THE PRINCIPIA.

THE PRINCIPIA

OR

THE FIRST PRINCIPLES OF NATURAL THINGS

TO WHICH ARE ADDED

THE MINOR PRINCIPIA

AND SUMMARY OF THE PRINCIPIA

BY

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CORRIGENDUM.

Vol. ii., p. 406, paragraph 82, *read* fifth *for* fourth.

THE PRINCIPIA.

CHAPTER XIV.

THE DECLINATION OF THE MAGNET, CALCULATED UPON THE FOREGOING PRINCIPLES.

It is now necessary to deal with the declination of the magnet, and first to explain theoretically the cause of the declination, and the origin of its variation. The remarkable and well-known phenomena of the magnetic needle, and its strange peculiarities, could not but be a source of perplexity to the minds of many; for the declination not only varies in every place, and in every part of the earth is dissimilar to itself, but also undergoes an annual mutation. This has for a long time been an apple of discord; but he who succeeds in gaining possession of it, will also succeed in carrying away the palm. The discovery of this secret will indeed be of immense service to the world, especially to mariners, who will, consequently, know the declination of their needle, and become more or less acquainted on their voyages with their bearings eastward or westward; that is to say, with the longitude. Before, however, we come to the reasons and causes of the variations, and of the remarkable variability of the magnet, it may be well to explain the practical difficulties of making observations, and to indicate the doubtful and equivocal character of those which have hitherto been made. For with the exception of those which have been taken at Paris, London, Berlin, and a few other places, no complete reliance can be placed upon them. Indeed it is questionable whether the tables do not differ from the true declination of

the place either by half a degree, a whole one, or even one and a half; so that whoever assumes all the observations to be true and reliable, and make them serve as the basis of his calculations, may deviate very widely from the truth. The chief causes of difficulty in making observations, as known to the learned world, are the following:—

1. If a minute portion of iron be anywhere in the vicinity, the needle used for observing the declination at once deviates from its true magnetic meridian, and moves in that direction more or less sensibly. Nor does it return to its proper meridian, whatever means may be used; neither can the observer foresee the particular quarter in which the portion of iron lies, and consequently he must be ignorant whether the needle occupies its true meridian or some other which is not the true one. It is well known that iron is found in all matter; as, for instance, in metals, stones, wood, and earth. If, therefore, in the box, or in the brass or copper of which the box is made, there is any iron, the needle is at once displaced from its true meridian. Experiment proves that small portions of iron in copper may attract the needle; if, then, there is the slightest amount of iron anywhere in the box, the meridian of the declination becomes immediately doubtful and indeterminable. If there is no iron in the box, but particles of iron in the post on which the box with the needle is placed, or in any adjoining wooden, stony, or chalky substance, the magnet immediately deviates and is deflected. Iron lies concealed in wood and stone; particularly in the chalk and stone of brick, because each consists of clay, which, when calcined and burnt, melts the iron and diffuses it within. I shall say nothing of nails in windows and shutters, of lattice-bars, and of other pieces of iron which are often visible to the naked eye. These, although situated several inches away, may deflect the magnet from its true meridian. Should there be in the vicinity a mineral mountain impregnated with any portion of iron, or should the earth contain some, and the air be consequently filled with its effluvia, the needle immediately deflects itself from the true meridian, and advances one or two degrees; this it has

been observed to do, even at a distance of several yards from the disturbing cause. Such then are the disturbing causes arising from iron, which the observer in vain endeavours to foresee, and which nevertheless interfere with the position of the needle, rendering observation uncertain, by causing a difference of one or more degrees. Also if the observation is taken at sea, on board a ship, the same causes are in operation to deflect the needle from its meridian. To this we may add, that if there be any magnet at a distance, as is generally the case with those who pursue observations of this kind, it will immediately withdraw the needle from the true degree of declination and bring it into another.

2. The needle may also be caused to deviate by a draught of air; for if wind be allowed to blow freely into the room, or to enter through chinks and other openings in the windows or walls, and it reaches the needle, the latter is soon brought into a state of aberration, and moves to the next degree instead of keeping to the one which it ought to occupy. Indeed, often some breath of the mouth, particularly when the observer is closely inspecting the quadrant, the degree, and minute of declination, will find its way to the needle, and cause it to deviate so as to render questionable the accuracy of the observation on that day, or on that hour of the day.

3. There may also be numerous defects in the needle itself; for a needle ought to be so made as to be capable of maintaining upon its pivot every kind of equilibrium. If there be anything to destroy the equilibrium, this will immediately affect the observation of the declination. If, for instance, the little cone which fits on to the pin is not in the true and central point of motion, the needle will incline immediately to the north or to the south, more or less upwards or downwards; or will decline more or less to one side than to the other, which may make a difference in the observation of the minutes. If the pin be not as sharp as it ought to be, the motion of the declining needle becomes slower and is more retarded. If the point of the pin, or the little cone upon it, should by length of time have become rusty, so that the original velocity and freedom of movement are

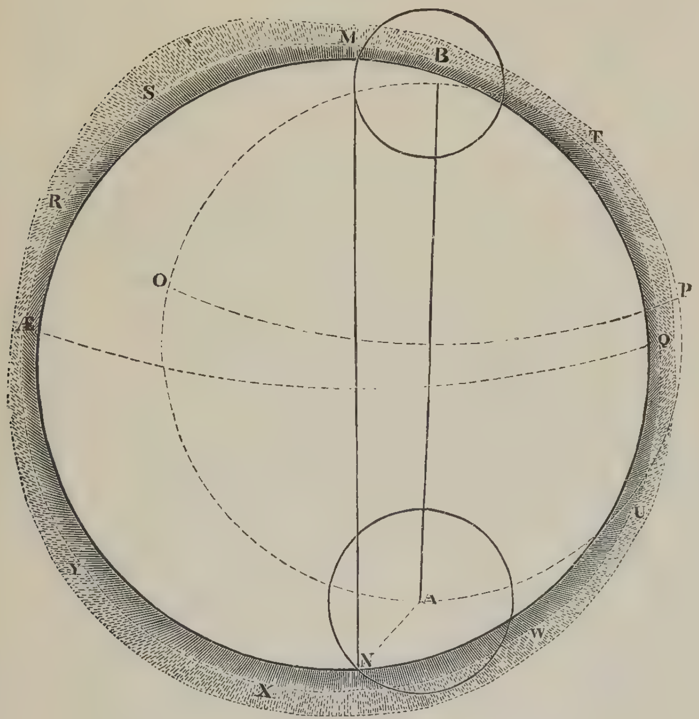
retarded, it will in this case show a declination with a difference of several minutes, or it may be a whole degree, instead of keeping to its true meridian. Similarly if the needle has begun to be dulled or corroded with rust, its movements immediately become sluggish, and the declination uncertain; or its motion is more difficult because the motive force is weaker. There are many other causes which might be assigned, and which operate in impeding the motion of the needle; the recital of all these would be tedious.

4. If the plane upon which the compass is placed and with which the observations are taken, is not perfectly horizontal, but inclines in any direction, particularly toward the east or west; then, although the needle, suspended on the pin and moving freely, endeavours to keep to the horizon, yet the plane of the box inclining to the right or left, makes the observation inaccurate, at least to the extent of some minutes. The eye of the observer, looking in a straight line from the rose of the needle, to the degree and minute of the quadrant, passes on to the degree or minute of the higher plane; and thus assumes as genuine what is only a fallacy. Hence if we move the box from one place to another, we shall find the needle ceasing to point to the same minute as it did in its first locality. This arises both from the cause we have specified, and also from others; to say nothing of the quadrant not being divided into degrees and minutes as accurately as it ought to be, or of the sides of the instrument not being perfectly parallel with the line running east and west, or north and south in the quadrant.

5. We may also add, that the observation is rendered doubtful if the needle is too heavy, or if its magnetic force is too feeble; for this will cause the movement to be slower and carry it over the neighbouring degree. Being too sluggish to move farther it remains at rest, and stops short of its proper position. This is particularly the case in northern regions, where the needle does not tend so strongly to its true magnetic meridian as in places nearer to the equator. The reason is as follows: the particles of the magnetic element lie near the magnetic equator in a horizontal line, one particle there being connected with

another in a horizontal direction. But nearer to the magnetic pole the particles change from a horizontal position, to one gradually more oblique; till near the pole they become perpendicular. For when the needle or the magnet is kept in its position of declination by the magnetic element, an element which operates upon the sphere of the magnet or needle, and directs it towards

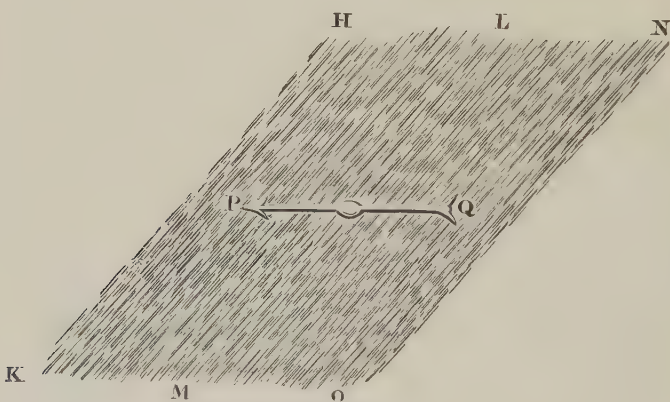
Fig. 84.



the poles, and when the particles of the element are more erect, they cannot operate so strongly upon the sphere of the magnet or needle as when the same element maintained a horizontal position. In fig. 84, let BOAP be the earth; B and A the two poles of the earth; OP its equator; M the north magnetic pole; N the south pole; ÆQ their equator; MÆNQ is also the earth; but this circle passes through each magnetic pole. Near the poles

M and N the particles of the element are erect, or are perpendicular to the horizon. But at a distance thence, as at T or S, they are in an oblique position; that is to say, oblique in regard to the earth; and this obliquity is the same with the magnetic inclination. Near the equator in ÆQ, the particles of the same element lie horizontally; whence again they gradually become erect toward the other pole in N, and so on. The obliquity of this element is best observed by the inclination. When, therefore, the magnet or needle in its declination is urged by the arrangement of the particles of the magnetic element, then the needle evidently

Fig. 85.



receives a direction in the element according to the position of the particles. If the arrangement is parallel, as in fig. 82 (p. 514, vol. i.), where all the particles of the element lying horizontally regard both poles, the needle is kept firmly in that position; for the current of the particles acts directly upon the sphere of the needle; but if the particles of the element are in an oblique position, as in fig. 85, then the particles act obliquely upon the sphere of the needle PQ, and urge it further downwards rather than in the polar direction; and the more oblique the position, the more feebly do they urge the needle toward its meridian. For the force affecting the needle is twofold; one urging it downwards, another horizontally, or in a polar direction. When

the particles are more erect, then the force urging the needle downwards, or into the position of inclination, is stronger than the one which urges it toward the horizon, or into the position of declination. Near the pole itself, or at some degrees distant, there can exist no directive force of declination. This is the reason why the declination needle is urged more feebly toward the magnetic meridian, in the northern and southern shores, than in the equinoctial regions; and that if there is the slightest obstacle or cause of retardation, it deviates with the greater facility from the true degree of declination, so as to prevent the various positions from being observed with accuracy.

6. Even the most accurate mathematicians may frequently be in error in taking observations of the meridian of a place, though it ought to be perfectly exact. How necessary it is to be exact in taking the true meridian of a place, is perfectly well known. If the point or needle which is set up for this purpose is not sufficiently pointed, or not set up perpendicularly: if the aperture (for it is in this manner the observation is generally made) is not exactly perpendicular to the horizon; if the plane, in which the line of the meridian is to be drawn, deviates in the least from the horizontal, or is otherwise unequal, immediately an error enters into the observation, the observer not knowing it, and a meridian is obtained different from the true one by one or two degrees. So that if we wish to observe the declination in reference to this meridian, the error of meridian will affect the reading of the declination, which will therefore be erroneous. The reasons why a meridian once found and recorded, may not be the true one for the following years are various. Cracks may have developed in the observatory, or it may have become slightly elevated, or have sunk slightly; in which case the meridian at first taken may be wrong by several minutes.

7. The declination also will be wrong, unless the altitude of the pole is observed as accurately as possible; for if the altitude is assumed as less or greater than it is, and if the declination is determined in conformity with the observation taken at that altitude, the real declination at such a latitude will be

different from the one assigned. The exact observation of the latitude in places nearer the pole is highly necessary; where at every different degree of latitude a considerable difference exists in the declination. As for instance, at the present day at degrees 50, 60, 70, 80 of longitude west of London, and at an altitude of the pole of 50 or 60 degrees, as also at the same latitude from the pole, at 100, 110, 120, 130 and 140 degrees of longitude east of London, there exists at any one degree of latitude a very sensible difference in the declination. A small irregularity, therefore, in the observation of the latitude gives rise to a wrong declination; which at the given latitude must be different from the one assigned. Mariners, and all who take the altitudes of the pole roughly with quadrants and their radii, may easily suppose a certain latitude to be 50 degrees; although if taken with perfectly exact instruments, it would be 49 or 51 or 52; so that we must not blindly and confidently take for granted all the observations of the latitudes which have been taken by navigators, and consequently the declination existing at that latitude. In those places where there are very skilful mathematicians, and where very accurately divided quadrants are used, the true latitude of the place may indeed be taken; but not where there are less skilful observers, using instruments not so exact; still less so where the plane upon which they stand, on board a ship for instance, is unsteady and moves with every wave; and this too at the moment when the latitude is taken, a process which requires some interval of time to complete.

8. Longitudes also are determined wherever the magnetic declinations of the needle are given, both on land and at sea. The longitude itself is known principally by the course and speed of the ship every hour, and every day, and which are entered in the log-book daily. But the longitude on land frequently baffles the most experienced mathematician; what, therefore, must be the case at sea! Even now the longitudes of places are not perfectly known; as for instance, of those upon the shores and coasts of Africa, Asia, and America, although they have been

taken by mariners and captains of vessels, who have either measured their course in the foregoing manner according to the longitude, or by the times of the eclipses, which, compared with the times in which they occur in other places, have enabled them in some measure to supply the longitude; a calculation which may be true, but only in so far as the times in which the eclipses occur have been observed with accuracy by persons otherwise unskilful. But at sea, where conjecture alone determines all the limits of the longitude, the degrees are often assumed as 10 or 20 nearer the first meridian, or more distant from it, than is true. Since, therefore, the knowledge of the longitude is still so uncertain, and yet a longitude is determined, and also a declination of the needle at the longitude thus determined, it follows that where there is error in the longitude, there is error in the declination. This at the given longitude must be different, and at the given degree of longitude must be greater or less by a difference often of several degrees, even as much as 3, 4, 5, 6, or 7. The point of chief importance, however, is from the given observation to learn the progress of the declinations when travelling west and east, or north and south. For the declinations observed in our course may either coincide or differ by several degrees. We must not, therefore, so far trust to the experiments of navigators as to take them as the basis of our calculations, and found upon them our theory of magnetic declination. If there be a difference of 1, 2, or 3 degrees, we are not, therefore, to conclude that the method of calculation is itself erroneous, or not theoretically true. These subjects, however, will be better understood in the sequel.

9. The observations of the declinations which are taken at sea, where the ship is tossed about by the wind and waves, and when the feet, arms, and eyes of the observer are, therefore, in a state of constant motion, and the instruments and the compass itself rendered fluctuating and uncertain in their actions, it is no wonder then that some difference of minutes, and perhaps of degrees, may arise; particularly when we consider, that on the most fixed and stable ground, even where the observers

are skilful, an error of one degree often occurs. This may be concluded from the numerous experiments of those who have observed at one hour of the day a different declination from that which they observed at another; indeed, a different declination on one day from that which was observed on the following; although the declination of the needle is very constant, and obeys as constantly as possible its first mobile or magnetic element; changing its position with the change of the times; the declination being increased or diminished according to causes which exist in the change of arrangement of the particles in the element itself. This change cannot be made sensible every hour or every day, but is nevertheless a defect in the observation which consequently becomes uncertain and diverse at different times for the reasons above mentioned, and often escapes the sagacity of the mathematician himself. Many proofs of the variations which occur on the same day, arising solely from the observer himself, and from the causes above mentioned, are given by Musschenbroek in his treatise (pp. 156-159). His words are as follows:

"I have intimated above, that not only every year but also every month and every day the declination is different; as is evident from the observations made by father Gui Tachard in the year 1682. For when in the presence of the King of Siam, in the city of Louvo belonging to that kingdom, he was attending to the needle, he found that one day it had declined toward the west 16 minutes; the second day 31 minutes; the third day 35 minutes; the fourth day 38 minutes. On other days of the same year, and between which there was no great interval, he observed a deviation of 28 minutes; on another day a deviation of 33 minutes; and on a third day a deviation of 21 minutes. See his *Voyage de Siam*, Paris, 1686 (pp. 319-321). These seven observations were made beyond a doubt within the space of a month; and from these it is evident that the needle exhibits some variation every day. Whether any one else before this father has ever observed this daily mutation, I know not; but I am able to confirm it from my own experience, as follows:—

	The Needle declined. Deg.	Min.		The Needle declined. Deg.	Min.
1728. 8 March .	13	20	1728. 17 April	13	15
8 April .	13	15	18 . .	13	15
10 . . .	13	19	19 . .	13	15
11 . . .	13	20	20 . .	13	18
12 . . .	13	20	21 . .	13	15
15 . . .	13	14	22 . .	13	15
16 . . .	13	15	23 . .	13	15

"But Graham, the celebrated mechanician of London, has given very minute attention to this circumstance, and has taken many observations which he has inserted in the English *Philosophical Transactions* (vol. xxxiii. p. 96); and as these are the best that have yet been made, I will here subjoin them, since they entirely confirm and illustrate both our own observations and those of Tachard, which at first sight might appear to be uncertain.

"He first constructed a very accurate needle, of considerable length, well rubbed upon a most powerful magnet, and inclosed in a copper box which contained the arc of a circle on which degrees and minutes were marked. This box was placed upon the meridian line, so that the declination of the needle toward the west might be the better observed. He then found the following results:—

Declination of the Needle on March 8, 1722, Deg.	Min.	Hours.	Min.	Another Needle within a wooden box. Deg.	Min.	Declination of the Needle on March 8, 1722. Deg.	Min.	Hours.	Min.	Another Needle within a wooden box. Deg.	Min.
14	30—	3	0	14	25+	14	20	4	15	14	15
14	20	3	15	14	20	14	25	5	0	14	20
14	15+	4	0	14	10	14	25	5	30	14	20
14	15	5	45	14	10	14	0+	6	48	14	0
14	0	5	57	14	0—	14	0	6	54	14	0—
14	0—	6	8	13	55	14	5	7	5	14	0+
13	50	6	15	13	40	14	10	7	15	14	5
14	20	6	38	14	15+	14	0+	12	0	14	0+

(*Philosophical Transactions*, vol. xxxiii. p. 102.)

The sign + denotes something more.

The sign — denotes something less.

"From these experiments we find that the declination of the needle varies nearly every hour; in fact, almost every minute, as some of the observations prove.

"2. Two needles rubbed against the same magnet have a different declination; one in a copper box showing a declination of 14° 30′, the other in a wooden one of 14° 25′.

"3. It is evident that the declination is changed simultaneously in every needle, but not equally; for at one time it is greater in one needle; at another time greater in another. Both first observations with the needle in the copper box prove that the variation = 10′; when in wood the difference of the variation = 5′. But the third variation in the copper box differs from the second only 5′, while the third in the wooden box differs from the second 10′.

"4. But within the space of 3 hours 8 minutes, the variation in each needle = 30′.

"I wish the observer had at the same time attended to the winds and their changes; possibly he might have discovered something affecting the observation under these circumstances.

"We shall here, however, add other observations made on the following days; from which it is evident that these mutations in the needle are happening always and daily; indeed, even every hour.

Declination.	Deg.	Min.	Hours.	Min.	Declination.	Deg.	Min.	Hours.	Min.
March	14	10	9	30	March	14	15+	12	45
9	14	10+	10	0	10	14	15+	2	0
	14	10	10	15		14	15	3	30
	14	10+	10	30		14	15+	4	0
	14	15	11	0		14	15—	5	30
	14	0	11	15		14	10	6	0
	14	0	11	50		14	0	6	15
						14	0	6	30
March	14	10+	10	0		14	0+	7	30
10	14	15	11	0		14	5	7	45
	14	15	12	0		14	0+	12	0

(*Philosophical Transactions*, vol. xxxiii. p. 103.)

"Many more observations may be met with in the above-mentioned *Philosophical Transactions*. The observer remarks that he had made more than a thousand observations in the same place, with the same needles, all of which were similar to one another. These experiments are obviously opposed to those which Cabeus has mentioned in *Philosophia Magnetica* (lib. i. cap. xvi. p. 52); where he rashly affirms that in the same place the declination is always the same.

"Müller, in his *Collegium Experimentale* (p. 237), adduces an observation of his brother, who remarked, that at the tops of mountains the needle declines 10, 20, 50, and even 90 degrees more than at their bases; and that this obtains on the mountains of Bohemia, and near the ancient Brisacus; he also says that it obtains in the mountains of Saxony. This paradox in mountainous regions is worthy of further examination, and requires further confirmation; in which case much additional light might be thrown upon the doctrine of magnetism; for the iron which many of the mountains contain, may give rise to considerable varieties in these and similar observations" (*op. cit.* pp. 156-159).

Thus far Musschenbroek.

What ground then, I would ask, is there for believing that within a few minutes of time the needle or its declination is liable to so many mutations, when after all it may possibly be an error of observation; a contingency which I consider to be unquestionable. The very experiments of Graham demonstrate that two needles rubbed against the same magnet have a different declination; one declining in a copper box 14° 30′; the other in a wooden box 14° 25′. Also within the space of 3 hours and 8 minutes, the variation of each needle was 30′; a difference scarcely to be found within 3 or 4 years; nor can any vapour laden with iron effluvia and wafted by the wind, be the cause of such a variation.

I am apprehensive that the same contingencies, if I might venture so to speak, occurred to the Parisian observers: who remarked the same and similar declinations in the years 1720, 1721, 1722, 1723, 1724, 1725; viz., a declination of 13° with-

out any annual increase. Sometimes indeed they observed a retrogression; as in the years 1712, 1713; as also in the years 1714, 1715; although in the vast and permanent system formed by the magnetic element, which surrounds our globe and constitutes both the solar and planetary vortices, and which in succession of time, from natural causes, and by an undeviating law of connection, changes its situation and produces always a different declination, there cannot exist changes so light and secret as those we have mentioned. If therefore such great men as we have referred to, exact in their methods, and at no loss for proper opportunities, can be mistaken in their experiments; what are we to say of the ordinary and less learned class of observers, who hurriedly perform their experiments and publish them without thought?

Before proceeding to calculations, I will give here the observations of declinations made by various authors at different times and in different places.

I.

A general Table of Declinations at Sea, taken from nautical observations made by Portuguese, English, and Dutch mathematicians, as well as by members of the Society of Jesus. From Athanasius Kircher,[1] *for the years* 1500 *to* 1600.

	Declination. East. Deg.	Min.	Latitude. North. Deg.	Min.
From the Rock of Lisbon, 50 leagues towards N.W.	6	5	39	10
As given by others	7	0	39	10
	10	0	39	10
From Lisbon to the Cape Verd Islands .	8	30	39	10
From Cape St Vincent three or four leagues towards W.	5	38	39	10
From St Mary, one of the Azores, 9 leagues E.S.	2	20	39	10
At Fayal, and thence to Terceira . .	3	45	39	45
From Terceira towards Lisbon . . .	7	30	39	45
From the Island of Flores towards the west 40 leagues	8	30	39	10

[1] *Magnes; sive de Arte Magnetica.* Coloniæ Agrippina, 1643, pp. 387-392.—*Trs.*

	East. Deg.	Min.	North. Deg.	Min.
And from Cape Blanco 300 leagues	4	0	39	10
From the Island of Flores towards the east 70 or 80 leagues	0	0	39	10
From the same island towards W. 30 leagues	0	0	39	10
	West.			
In passing the meridian of the Islands of Flores and Corvo	1	0	39	10
From the Island of Flores 100 or 200 leagues towards the west	2	0	39	10
	1	0	39	10
In sight of the Island of Flores S.E.	5	37	39	10
From the Island of Flores, W. 230 leagues	3	30	39	19
Near Pico	1	30	39	19
From the Canaries 20 leagues	1	0	19	0
	East			
At the Canaries	5	37	32	0
From the Great Canary Island towards the north	4	37	32	0
From the Islands called Seluages	5	37	31	0
At the S.W. side of the Great Canary Island	5	20	28	0
From the Canary Islands 230 leagues	0	0	20	0
From observations taken while coming from the West Indies, shortly before reaching the Canaries	0	0	33	0
And shortly after passing them	5	37	27	20
From Palma towards Cape Blanco	3	0	24	0
From Cape Blanco nearly 2 leagues	2	40	21	0
W.S.W. 20	2	40	20	25
W. 63	5	37	19	20
W. 90	5	0	18	35
W. 100	6	0	18	35
E. 436	7	30	17	42
From Cape Blanco E. 470 Leagues	7	30	11	57
E. 476	7	36	16	35
E. 535	7	30	10	59
E. 595	5	0	10	15
E. 640	4	3	10	0
E. 700	1	3	9	20

	East. Deg.	East. Min.	North. Deg.	North. Min.
At Cape Verd	4	0	14	54
From the Cape Verd Islands 300 leagues towards W.	5	38	14	0
At the Islands of St Jago and St Nicholas .	2	38	14	0
From Cape Verd 100 or 120 leagues . .	3	45	14	0
From the Islands of Bravo and Jago 12 leagues towards W.N.W. . . .	4	30	14	0
From Mayo 46 leagues towards E.S. . .	5	8	14	20
According to other observations . .	3	30	14	0
From Cape Verd on the passage towards the East Indies	4	0	6	0
According to observations made in passing the Equinoctial	5	0	0	0
At the Island of Trinidad . . .	0	0	9	46
From this island 90 leagues towards E.W. .	1	0	9	46
According to other observations . .	2	0	9	46
	West.			
At Margaritta, and at St Cruz near St Juan de Porto Rico	0	0	23	0
From St Juan de Porto Rico, N.N.W. .	8	0	14	20
In the meridian of the Island of Barbadoes, 15 leagues from Martinique . .	1	0	14	20
At the Island of Guadaloupe . . .	1	0	15	18
At Cursands [?] and West India Islands .	4	0	12	13
At the mouth of the river Hacha . .	7	36	11	20
Off the river Mayo	15	0	31	0
Near Cape Corrientes in the Island of Cuba	3	0	9	30
At Cape St Anthony in the Island of Cuba	13	0	22	0
At Cape Cameron	5	0	25	40
At Cape Florida	3	0	25	30
Towards the north of Cape Florida . .	13	0	28	0
Near the coast of America	11	0	35	30
From the Bermudas, 140 leagues towards the west	10	3	30	35
From Cape Race, S.S.W.	6	30	39	40
	East.			
From Sierra Leone, W.S.	6	0	7	0

	East. Deg.	East. Min.	South. Deg.	South. Min.
From Cape Sierra Leone for 220 leagues towards the west, it constantly increases from one degree to	6	45	—	—
At Cape St Augustin	7	0	7	16
From Cape St Augustin 100 leagues . .	11	6	6	30
At the Island of Fernando da Noronha, near Brazil	3	45	2	20
In the meridian of Trinidad, near Brazil .	11	10	8	0
Between the Islands of Trinidad and Ascension	12	10	20	30
At the Island of Ascension . . .	10	0	20	0
In the meridian of Trinidad, towards E. .	14	53	27	0
Between the Islands of Trinidad and Tristan d'Acunha	18	0	36	20
	19	0	36	20
From the shore of Brazil, 14 leagues towards the east	12	30	19	30
From the shore of Brazil 150 leagues .	10	0	18	0
At Cape St Vincent in Brazil . . .	12	0	—	—
From the shore of Brazil 100 or 120 leagues	8	30	17	0
	7	30	18	0
From the Island of Ascension 20 or 30 leagues towards the east, and at the rocks of Penedo di St Pietro . .	5	30	—	—
Between the Islands of Ascension and St Helena	7	30	0	0
At the Island of St Helena the declination varies 2, 3, 4, 5, 7, 9 degrees. At the Islands of Martin Vas . . .	13	0	19	0
From these Islands towards the north 30 leagues	18	30	35	25
Beyond the Islands of Tristan d'Acunha 70 leagues	16	53	33	0
From the Islands of Tristan d'Acunha, to the west	17	52	34	35
At the Islands of Tristan d'Acunha . .	19	0	—	—

	East. Deg.	East. Min.	South. Deg.	South. Min.
On the passage from that island off the Cape of Good Hope	14	0	23	25
Near Cape Frio	13	0	23	30
According to other observations . .	12	0	23	30
From Cape Frio towards the west off the coast of Africa	17	0	17	19
	18	0	17	19
From Cape Frio 125 leagues towards the west	11	8	18	20
At Port Desire	5	0	47	40
At the entrance to the Straits of Magellan .	5	30	53	15
In the Straits	5	0	54	27
From the Cape of Good Hope 900 leagues W.N.	15	52	26	50
At the Bay of Soldan (Sudanna Bay) .	0	0	33	55
	1	30	33	55
At the Cape of Good Hope . . .	0	15	36	10
	1	30	35	10
	2	0	35	0
	West			
From the Cape of Good Hope, 36 leagues S.W.S.	4	10	35	25
And 28 leagues thence	3	50	35	30
From the same Cape towards S. . .	3	45	35	16
And towards W. 40 or 50 leagues . .	3	0	35	40
At Cape de Agulhas, near the Cape of Good Hope	0	0	35	19
And thence towards the east 80 leagues .	0	0	35	10
From Cape Aguilas towards N.E., in sight of Terra Nova	3	47	34	20
At Cape Corrientes beyond the Cape of Good Hope	7	30	25	0
	11	0	25	40
			North	
At the Primera Islands, off Mozambique .	15	0	18	0
In the Island of Mozambique	12	0	14	45
At the Island of Zanzibar	7	46	8	10
	10	0	7	30

	West. Deg.	West. Min.	North. Deg.	North. Min.
At the Island of Almirante, near the Equinoctial	13	0	0	0
Near Cape Guardafui	8	15	13	15
At the mouth of the Red Sea	5	15	12	15
At Port Igidid [?]	0	40	22	0
At Xuarit [?]	0	15	0	0
	East			
At the Bay of Sidon	2	35	33	30
	West			
At Goa in India	17	0	15	20
According to other observations	16	40	15	20
			South	
At the Comora Islands	13	0	12	31
In the Island of Madagascar, near the Bay of St Augustin	15	0	15	20
At Cape Romain, in the Island of Madagascar	8	30	26	0
From the same Cape, 110 leagues W.S.W.	14	14	46	34
In the Bay of Antongil, in the Island of Madagascar	25	0	17	0
According to other observations	20	0	0	0
In the Bay of Tassarin [?]	5	30	0	0
Western coast of the Island of Saya de Malha	15	0	11	30
At the Island of Pagapez	23	11	10	0
At Grace Island, 36 leagues W.S.W.	24	11	9	20
At the Arenaria [?] of India	8	30	30	0
At the Island of Didaci Roix	21	20	20	0
At the Islands of Los Romeros, 68 leagues S.W.	24	15	31	0
From the same islands 110 leagues	21	20	30	40
At the Arenaria [?] of Adu and Candu	19	30	6	0
At the Island of Didaci Gratiosi	24	0	9	0
From this island towards W. 20 leagues	22	0	7	30
At the Island of Didaci Roderici	20	0	35	0
	East		North	
From the same island, S. and S.E.	25	0	36	0
	24	0	36	0
	25	0	36	0

	East. Deg.	East. Min.	North. Deg.	North. Min.
At the Maldive Islands	17	0	0	0
At Cochin in the East Indies . . .	13	0	9	40
From Cochin towards the Maldive Islands, S.S.W.	—	—	8	0
At 8 and 10 degrees, south latitude .	16	52	10	0
At Zeilah	15	30	9	0
At the Island of Pulo Batu [?], according to some 4°, according to others . .	2	0	4	0
At Acheen in Sumatra . . .	8	0		
On the west side of Sumatra in the Island of Priamaria	5	40	South 0	21
Near Bantam in Java	5	0	—	—
	4	30	7	0
At Maderia	2	30	6	36
In Java Major	0	0	7	30
In the Philippine Islands the declination is various				
At Macao in China	1	30	22	30
At the mouth of the Canton River . .	0	0	25	12
In Japan	8	30	40	30
In the Salomon Islands	4	0	—	—
From the Island of Ferdinand, 200 leagues in the Mari del Zur	0	0	—	—
In Davis' Straits the greatest declination has been observed by the Dutch .	50	0	62	50

"*Observations made in the Northern Regions by the English and Dutch.*

	West. Deg.	West. Min.	North. Deg.	North. Min.
"At Eishaven in Nova Zembla . .	22	30	76	0
On the western coast of Nova Zembla .	26	0	76	0
From Nova Zembla, 20 leagues towards the west	31	0	73	0
At Cross Island, near Nova Zembla . .	17	0	73	0
At the Nova Terra of the Dutch, commonly called Nielandt	16	0	81	0

	West. Deg.	Min.	North. Deg.	Min.
Island of Vaigatz	7	0	71	0
James Island	7	30	70	40
At the Straits near Pechora	3	30	69	10
At the North Cape	1	0	71	30
Midway between Friesland and Labrador	28	0	62	0
According to observations made in a voyage along the English coast, from Yarmouth towards the north	East 12	40	55	14
On a voyage from London towards Russia, at one time to the west, 3, 7, 8 deg.; at another time, to the east	4	0	65	40
	5	10	64	30
	3	0	66	30
	West			
At Antwerp	9	0	51	0
At Amsterdam	9	30	52	20
At London	11	30	51	32
At Portland	10	0	51	32
Churchyard of St John, on the coast of Cornwall	8	0	50	30
At Youghal in Ireland	10	0	49	55
From Bellisle 350 leagues towards the west	1	0	52	10
From Scilly, W.N.W. 235 leagues	0	0	45	0
From Scilly, W.N.W. 514 leagues	10	0	60	0
Thence, N.W.N.	16	0	63	30
And thence again N.W.	22	0	66	0
From this place, N.W.	28	0	73	0
From this, W.W. 40 leagues	33	0	73	0
At Cumberland Island	30	0	64	0
At Cape Sanderson	28	0	72	12
At Cape Race, in Newfoundland	8	0	47	0
From Cape Race, S. W.	2	52	34	35
	35	30	5	37
	East			
At Cape Finisterre	8	30	39	40
Coast of Virginia, 36 deg.	12	0	0	0
Island of Martin, one of the Camertan Islands 21 deg.	0	0	21	0"

II.

A Table showing the Longitudes and Latitudes of various places, together with the Declination of the Magnet; derived chiefly from the observations made by Jean Le Tellier in his Voyage faiet aux Indes Orientalles, *by Athanasius Kircher.*[1]

Longitude.		Latitude.			Declin. East.		Longitude.		Latitude.			Declin. East.	
Deg.	Min.	Deg.	Min.		Deg.	Min.	Deg.	Min.	Deg.	Min.		Deg.	Min.
0	17	16	50	North	2	40	7	39	21	8	North	4	47
0	48	45	46		5	15	7	55	33	44	South	13	20
1	0	17	33	South	9	30	8	0	23	30		13	0
1	3	20	11		11	27	8	12	52	8	North	11	0
2	0	22	56		13	0	8	15	2	26		4	10
2	32	9	50		6	40	8	30	38	55		10	0
3	6	7	0		5	45	9	2	29	2	South	13	15
3	20	25	34		14	0	9	40	6	16	North	2	15
3	40	4	50	North	3	50	9	40	7	19		2	30
4	55	33	44	South	12	34	9	50	29	46		6	39
5	18	40	0		7	30	10	10	4	10	South	5	30
5	22	1	40		5	20	10	10	7	39	North	2	35
5	28	25	11		15	20	10	13	31	42		6	16
5	39	3	14		7	34	10	35	3	19		3	30
5	45	2	30		7	12	10	56	35	40		7	10
5	51	1	30		6	0	11	10	8	15		2	40
6	0	1	6		5	0	11	30	46	50		8	0
6	0	4	27		7	25	11	50	30	42	South	12	30
6	6	9	36	North	3	10	12	15	7	0		6	0
6	10	14	30		2	45	12	30	49	9	North	8	50
6	10	29	45		6	0	13	52	8	4	South	6	15
6	15	27	22	South	13	30	15	10	50	10	North	9	0
6	40	14	50		11	0	16	15	31	20	South	11	25
6	40	2	54	North	4	0	16	18	31	0		12	0
6	50	19	24		3	33	17	0	55	0	North	12	40
7	9	0	20		4	15	18	6	51	24		11	30
7	35	0	40	South	4	40	20	18	33	31	South	10	15

[1] *Magnes*, pp. 394-400.—*Trs.*

Longitude. Deg.	Min.	Latitude. Deg.	Min.		Declin. East. Deg.	Min.
20	26	15	0	South	6	0
21	55	16	0		5	30
22	42	16	24		5	20
23	0	50	10	North	6	30
23	45	17	20	South	5	15
25	15	18	20		5	10
27	18	34	16		8	30
27	50	20	0		5	0
31	14	34	2		5	0
33	40	34	2		3	0
35	0	34	9		2	20
36	16	34	3		1	40
36	20	26	15		2	0
39	30	28	26		0	45
39	46	34	27		0	25
41	10	34	13		0	5
347	25	27	36	North	4	0
348	55	36	0		4	0
349	51	35	20		3	40
350	0	35	0		3	50
351	0	8	30	South	3	10
352	20	37	0	North	3	20
353	7	22	25		3	30
356	17	37	40		3	45
356	22	14	20		3	0
356	30	19	20		3	15
356	42	32	36		3	50
356	56	37	25		3	30
357	25	39	30		4	0
357	35	18	16		3	0
357	48	12	48		3	15
357	27	11	15		3	0
359	40	9	25		3	15
359	40	44	0		4	0

Longitude. Deg.	Min.	Latitude. Deg.	Min.		Declin. West. Deg.	Min.
42	7	34	0	South	1	40
43	16	34	16		—	16
43	53	32	0		—	30
44	32	34	4		—	46
44	44	32	45		1	40
45	37	33	42		1	15
46	16	34	0		1	45
46	36	34	0		1	45
46	40	35	0		2	0
47	19	36	16		3	20
47	30	37	10		2	0
48	54	35	20	North	4	30
49	45	35	50	South	4	15
50	50	36	15		5	45
51	12	37	35		6	30
51	49	35	6		6	30
52	15	37	0		7	0
53	2	36	0		8	20
53	15	33	30	North	8	0
53	28	34	0	South	8	5
54	15	35	21		9	0
57	27	35	15		11	0
58	42	33	45		13	0
60	10	36	0		13	0
61	40	33	15		15	0
61	40	36	48		14	30
64	13	37	0		16	0
64	18	27	42		15	0
65	20	32	20		16	30
65	24	25	44		15	10
65	37	17	44		12	30
66	6	24	50		15	20
66	20	19	20		13	7
66	24	32	47		16	0
66	40	14	50		11	0

Longitude. Deg.	Longitude. Min.	Latitude. Deg.	Latitude. Min.		Declin. West. Deg.	Declin. West. Min.
67	13	24	5	South	15	40
67	15	29	0		15	30
67	20	20	39		13	30
67	27	16	6		12	50
67	47	21	50		14	0
68	20	34	0		18	30
69	11	25	4		15	39
69	36	28	0		17	10
69	52	5	0		14	5
69	56	34	40		19	4
71	20	28	0		16	0
71	40	11	30		15	0
72	23	5	12	North	11	0
74	28	34	5	South	22	50
75	9	31	0		21	0
76	52	2	0	North	14	45
77	33	31	0	South	22	30
78	16	32	20		23	0
78	54	31	0		22	50
79	5	3	48	North	15	40
80	39	31	50	South	23	30
81	45	32	0		23	15
81	54	6	0	North	16	30
83	57	30	50	South	25	22
84	22	14	20	North	17	0
84	25	13	45		18	0
84	30	73	20		25	0
85	53	10	20		17	0
86	16	12	0		18	0
86	25	13	45		18	30
86	36	30	10		24	50
87	0	69	30		24	30
87	2	30	0	South	24	0
88	32	13	18	North	19	40
91	32	12	45		20	38
92	1	26	24	South	24	20
92	30	26	53		22	0
93	18	12	45	North	20	30
93	35	26	20	South	21	48
93	48	25	15		23	30
94	0	75	35	North	33	0
94	15	25	42	South	21	50
94	57	13	6	North	20	10
95	0	19	20	South	22	0
95	15	24	37		21	0
95	50	23	43		20	40
96	39	13	22	North	19	0
96	40	23	32	South	23	0
98	14	13	42	North	18	0
98	44	22	50	South	22	0
98	50	19	27		17	40
100	33	14	10	North	16	30
101	5	16	18	South	16	20
101	50	20	56		19	30
102	35	15	25		15	20
102	38	15	0		14	35
103	12	14	10	North	16	0
104	20	19	56	South	17	30
105	0	15	30		15	10
106	9	13	0	North	15	30
106	20	19	56		16	36
106	38	13	33	South	13	0
108	25	11	27		11	40
108	30	19	5	North	15	0
109	20	10	32	South	11	0
110	35	5	54	North	13	40
111	0	18	5	South	13	0
111	53	8	30		9	47
112	15	17	10		12	0
112	23	8	0		9	16

Longitude. Deg.	Min.	Latitude. Deg.	Min.	Declin. West. Deg.	Min.
113	50	6	59 South	8	40
114	51	6	42	8	0
114	3	5	12 North	11	0
114	35	15	2 South	10	30
115	45	6	24	7	30
116	30	6	26	6	40
117	32	14	12	9	30
119	23	2	0 North	8	0
121	59	12	57 South	7	30
123	43	0	10	5	45
125	50	1	53 North	5	15
126	—	9	40 South	5	0
127	14	5	0 North	4	0
127	15	7	26 South	4	30
128	33	1	9 North	4	0
129	50	3	46 South	4	15
129	12	0	26	4	0
130	59	12	57	7	30
141	40	4	36 North	3	30
207	0	8	40 South	1	30
344	30	77	12 North	27	0
346	0	37	0	0	0”

III.

A Table of Magnetic Declinations, observed by Mathematicians in various parts of Europe, at the request of Kircher [Magnes, *pp.* 401-403].

	Declination. Deg.	Min.	Latitude. Deg.	Min.
“ At Lisbon, from the relation of others by Chrysost. Gallo and Cristoforo Borro	7	39	39	38
At Evora in Portugal, according to Martino Martini	6	12	39	0
At Coimbra in Portugal, by the same .	6	3	40	30
At Madrid, by Cristoforo Borro . .	5 (about)		40	45
At Paris, by Marin Mersenne and Pierre Bourdin	11	0	48	40
At Tours in France, by Jacques Grandami	4	50	43	43
At Dole in Burgundy, by Vincent Leotaud	5	14	46	48
At Besancon, by Kircher . . .	5	0	47	15
At Lyons, by Kircher	4	30	45	10
At Tournon, by Antoine de la Loure .	3	51 East	45	16
At Avignon, by Antoine François de Payen, Peter de St Eligius, and Kircher	3	10	—	—
	4	0	43	42
	4	30	—	—

	Declination. Deg.	Min.	Latitude. Deg.	Min.
Montpellier, by Gulielm. Degner . .	3	30	43	30
At Arles, by Kircher	3	30	43	38
At Marseilles, by Piere Gassendi . .	2	40	43	20
At Digne, by Piere Gassendi . . .	2	40	43	0
At Aix, by Piere Gassendi . . .	2	36	43	25
At Villa Franca, near Nyssa, by Kircher	2	26 West	43	30
At Leghorn, by Jean François Niceron .	5	0	42	30
At Genoa, by Martino Martini . .	5	58	43	50
At Genoa, by Girolamo Bardi . .	5	30	43	50
At Milan, by Carolus Moneta . .	2	30	45	6
At Mantua, by Franciscus du Jardin .	0	30	45	12
At Bologna, by Giovanni Battista Manzini	3	0	44	16
At Ferrara, by Nicolaus Cabeus . .	5	50	44	10
At Parma, by Josephus Blancanus .	6	0	44	30
At Venice, by various observers . .	5	0	45	0
At Rome, by Giovanni Battista Giattini	3 (about)		—	—
At Rome, by Antoine Martini . .	2	50	—	—
At Rome, by Jean Casparus Berti .	3 (about)		41	56
At Rome, by Kircher	2	45	—	—
At Rome, Jean François Niceron . .	2	40	—	—
At Rome, by Franciscus Perseus . .	3 (about)		—	—
At Florence, by Jean François Niceron .	3	30	43	40
At Loretto, by Kircher . . .	4	0 West	44	10
At Bologna, by Carlo Antonio Manzini .	3	0	—	—
At Leghorn, by Niceron . . .	5	0	44	30
At Naples, by Jean Baptiste Zupi .	0	30 West	41	0
Cape Palinuro, by Kircher . . .	2	13	40	6
At Poala, by Kircher	2	30 West	39	50
At Tropia, by Kircher	2	40	38	32
At Messina, near Charybdis, by Kircher .	0	0	38	50
At Malta, by Franciscus du Jardin .	0	0	35	26
At Palermo, by Carolus de Vintimiglia				
and Fredericus Fontanerus . .	5	0	37	0
and Giovanni Paolo Chiaranda .	7	0	37	0

	Declination. Deg.	Min.		Latitude. Deg.	Min.
On Etna, near the three Chestnut Trees, by Kircher	6	0	West	37	40
At Syracuse, by Kircher . . .	6	(about)		37	15
At London, by William Gilbert . .	11	0		52	30
At Antwerp, according to various observers	8	30		51	48
At Louvain, by Joannes Ciermans . .	9	0		51	32
At Ghent, by Grégoire de Saint Vincent .	1	40		51	30
At Amsterdam, by Jodocus Hondius .	9	30		51	38
At Leyden, according to various observers	9	30		51	30
At Dortrecht, according to Mersenne .	2	(little more)		51	38
At Emmerich, by Jodocus Kedde . .	5	52		50	49
At Triers, by Kircher	6	24		49	12
At Cologne, by Johann Grothaus . .	3	0		50	36
At Cologne, by Lubertus Middendorff .	1	½		—	—
At Munster in Westphalia, by Laurentius Mattenkloth	5	48		51	46
At Paderborn, by Hubert Lintz . .	5	(about)		51	29
At Aschaffenburg, by Joannes Reinardus Zieglerus	6	20		50	8
At Mentz, by Henricus Marcellius .	6	7		5	30
At Fuld, by Kircher	4	30		50	38
At Wirtzburg, by Kircher	5	15		49	57
At Nuremberg, by Georg Hartmann .	8	(given variously)		49	30
At Heidelberg, by Kircher	6	10		49	10
At Innspruck, in the Tyrol, by Joannes Baptista Cysatus	2	0		46	55
At Ingoldstadt, by Jacques Viva and Wilhelm Gumppenberg . . .	4	30		48	40
At Ebersberg in Bavaria, by Michel Staudacher	4	26		48	37
At Fribourg in Brisgow, by George Schönberger	4	30		48	46
At Prague in Bohemia, by Théodore Moretus	5	30		50	20
At Olmutz in Moravia, by Conrad Balthasar	2	30		50	24
At Vienna in Austria, by André Cobavius .	0	0	West	48	20

	Declination. Deg.	Min.	Latitude. Deg.	Min.
At Gracz in Styria, by Jacques Honore Durand	2	0	48	10
At Wilna in Lithuania, by Oswald Krüger	3	40	53	0
At Nisvis in Lithuania, by Oswald Krüger	3	40	53	0
At Orsa in Lithuania, by the same .	3	40	53	0
At Constantinople, by various observers	0	0	43	5
At Aleppo in Syria, by Joannes Baptista Amicus and Aimé Chesaud . .	3	0	37	26
At Alexandria in Egypt, by John Graves, an Englishman	5	45	30	0
At Goa in India, by Joannes Uremannus .	17 (about)		16	0
In Narsingah in India, by Petrus Rubinus	12	0	18	30
At Canton in China, by Joannes Uremannus	0	0	33	0
At Macao in China, by Joannes Uremannus	1	30	22	0"

IV.

Declinations observed by M. Martini, in the year (as I think) 1638; and given by Kircher in his work [Magnes, *p.* 382].

	Declin. East. Deg.	Min.
"In the Port of Lisbon	7	39
Thence to the western coast of Maderia, gradually decreasing to	5	49
In latitude 28 deg. 25 min.	6	3
To the south of Palma 20 leagues	7	20
The same all the way to Cape Verd.		
To the west of Cape Verd 46 leagues . . .	7	30
In Guinea, under 7 deg. lat.	8	0
From Cape Verd, 220 leagues to the west, at a latitude of 18 degrees	5	0
But the needle is stationary at almost the same latitude, 340 leagues from Cape Verd . .	0	0

	Declin. East. Deg.	Min.
From about 15 deg. latitude to about 18, the needle is stationary, that is to say, for 150 leagues, and still more so from the Cape Verd Islands . .	0	0
From the 28th to the 30th deg. of latitude, the needle declines to the western coast of the Island of Flores, which is one of the Azores; from this towards the west, 40 leagues	1	12"

V.

The Declinations of the Magnet at the principal places in the Mediterranean; taken also from Kircher [Magnes, *p.* 385], *for the year* 1638.

	Declination. Deg.	Min.
"In the Stœchades Islands [Les Isles d'Hyeres] .	5	0
Island of St Honorè	4	10
At Genoa	5	0
At Cape di Corso, in Corsica	7	30
At Porto Longone, Island of Elba . . .	5	0
Cosmopolitan shore, ditto	8	0
In Porto Ferrajo, ditto	20	0
In Ænaria, or Procita	1	15
In the Lipari Islands, near Volcano . . .	2	19
At Messina, near Pharos at Charybdis . . .	0	10
At Malta	0	0
Near the Peloponesus	0	0
Off the eastern coast of Crete	15	0
At Alexandria, in Egypt	5	45
In the Archipelago, various	—	—
At Constantinople	0	0"

VI.

A Table of various Declinations for various years, inserted in Acta Eruditorum. *Lipsiæ* 1684 [*pp.* 387-390].

Names of Places.	Longitude from London. Deg.	Min.	Latitude. Deg.	Min.	Year.	Declination. Deg.	Min.
" At London .	0	0	51	32 s.	1580	11	15 East
	—	—	—	—	1622	6	0
	—	—	—	—	1634	4	5
	—	—	—	—	1672	2	30 West
	—	—	—	—	1683	4	30
Paris . .	2	25 East	48	51	1640	3	0 East
	—	—	—	—	1666	0	0
	—	—	—	—	1681	2	30 West
Uraniborg . .	13	0	55	54	1672	2	35
Copenhagen .	12	53	55	41	1649	1	30 East
	—	—	—	—	1672	3	35 West
Dantzic . .	19	0	54	32	1679	7	0
Montpellier .	4	0	43	37	1674	1	10
Brest . .	4	25 West	48	23	1680	1	45
Rome . .	13	0 East	41	50	1681	5	0
Bayonne . .	1	20 West	43	30	1680	1	20
Hudson's Bay .	79	40	51	0	1668	19	15
Hudson's Straits	57	0	61	0	1668	29	30
In Baffin's Bay, Sir T. Smith's Sound	80	0	78	0	1616	57	0
	50	0	38	40	1682	7	30
At Sea . .	31	30	43	50	1682	5	30
	42	0	21	0	1678	0	40 East
Cape St Augustin, Brazil . .	35	30	8	0 s.	1670	5	30
Cape Frio . .	41	10	22	40 s.	1670	12	10
At Sea, off the mouth of the River de la Plata . .	53	0	39	30	1670	20	30
At the eastern entrance to Magellan's Straits	68	0	52	30	1670	17	0

Names of Places.	Longitude from London. Deg.	Min.	Latitude. Deg.	Min.	Year.	Declination. Deg.	Min.
At the western entrance to those Straits	75	0 West	53	0	1670	14	10 East
Baldivia . .	73	0	40	0	1670	8	10
Cape Aguilas .	16	30 East	34	50	1672	2	0 West
	—	—	—	—	1675	8	0
At Sea . .	1	0	34	30	1675	0	0
	20	0 West	34	0	1675	10	30 East
	32	0	24	0	1675	10	30
The Island of St Helena . .	6	30	16	0	1677	0	40
,, Ascension	14	30	7	50	1678	1	0
,, St John	44	0 East	12	15	1674	19	30 West
,, Mombaza	40	0	4	0	1675	16	0
,, Socotra .	56	0	12	30 N.	1674	17	0
Aden, at the entrance to the Red Sea	47	30	13	0	1674	15	0
Terra Diego Roiz	61	0	20	0 S.	1676	20	30
At Sea . .	64	30	0	0	1676	15	30
	55	0	27	0	1676	24	0
Bombay . .	72	30	19	0 N.	1676	12	0
Cape Comorin .	76	0	8	15	1680	8	48
Ballasora . .	87	0	21	30	1680	8	20
Fort St George .	80	0	13	15	1680	8	10
In the west of Java	104	0	6	40 S.	1676	3	10
At Sea . .	58	0	39	0	1677	27	30
The Island of St Paul . .	72	0	38	0	1677	23	30
Van Dieman's Land	142	0	42	25	1642	0	0
New Zealand .	170	0	40	50	1642	9	0 East
The Island of the Three Kings, in New Zealand . .	169	30	34	35	1642	8	40
The Island of Rotterdam . .	184	0	20	15	1642	6	20

Names of Places.	Longitude from London. Deg.	Min.	Latitude. Deg.	Min.	Year.	Declination. Deg.	Min.
The Shore of New Guinea . .	149	0 East	4	30	1643	8	45 East
The western point of New Guinea .	126	0	0	26	1643	5	30 "

VII.

The following Table occurs in Christian von Wolff's Allerhand nützliche Versuche [*vol. iii. pp.* 197, 198].

" Longitude from London. Deg.	Min.	Latitude. Deg.	Min.	Year.	Declination. Deg.	Min.
0	0	34	30 S.	1675	0	0
16	30 East	34	50	1675	8	0 West
40	0	4	0	1675	16	0
44	0	12	15	1675	19	30
47	30	13	0 N.	1674	15	0
55	0	17	0 S.	1676	24	0
56	0	12	30	1674	17	0
58	0	39	0	1677	23	30
61	0	20	0	1676	20	30
64	30	0	0	1676	15	30
72	0	39	0	1677	27	30
72	30	19	0 N.	1676	12	0
76	0	8	15	1680	8	48
80	0	13	15	1680	8	10
87	0	21	30	1680	8	20
126	0	0	26 S.	1643	5	30 East
142	0	42	25	1642	0	0
149	0	4	30	1643	8	45
169	30	34	35	1642	8	40
170	0	40	50	1642	9	0
184	0	20	15	1642	6	20
6	30 West	16	0	1677	0	40
14	30	7	50	1678	1	0
20	0	34	0	1675	0	0
31	30	43	50 N.	1682	5	30 West

Longitude from London. Deg.	Min.	Latitude. Deg.	Min.	Year.	Declination. Deg.	Min.
32	0	24	0 S.	1685	10	30 East
35	30	8	0	1670	5	30
41	10	22	40	1670	12	10
42	0	21	0 N.	1678	0	40
50	0	38	40	1682	7	30 West
53	0	38	30 S.	1670	20	30 East
57	0	53	0	1670	14	10
57	0	61	0 N.	1668	29	30 West
68	0	52	30 S.	1670	17	0 East
73	0	40	0	1670	8	10
79	40	51	0 S.	1668	19	15 West
80	0	78	0	1661	57	0"

VIII.

"*A Table of Magnetic Declinations observed at Paris.*[1]

Year.	Declination towards the East. Deg.	Min.	Year.	Declination towards the West. Deg.	Min.
1550	8	0	1698	7	40
1580	11	30	1699	8	10
1610	8	0	1700	8	12
1640	3	0	1701	8	25
1664	0	40	1702	8	48
	Towards the West.		1703	9	6
1666	0	0	1704	9	20
1670	1	30	1705	9	35
1680	2	40	1706	9	48
1681	2	30	1707	10	10
1683	3	50	1708	10	15
1684	4	10	1709	10	15
1685	4	10	1710	10	50
1686	4	30	1711	10	50
1692	5	50	1712	11	15
1693	6	20	1713	11	12
1695	6	48	1714	11	30
1696	7	8	1715	11	10

[1] Musschenbroek, p. 152.

Year.	Declination towards the West. Deg.	Min.	Year.	Declination towards the West. Deg.	Min.
1716	12	20	1723	13	0
1717	12	20	1724	13	0
Another month	12	45	1725		
1718	12	30	November 6	13	15
1719	12	30	December 30	13	15
1720	13	0	1726, Dec. 6	13	45
1721	13	0	1727, Dec. 1	14	0
1722	13	0	1728, Jan. 3	14	0"

IX.

"*A Table of Magnetic Declinations observed at London.*[1]

	Year.	Declination. Deg.	Min.
By Borough . .	1576	11	15 East
	1612	6	0
By Gunter . . .	1622	6	10
By Gellibrand . .	1634	4	5
By Bond . . .	1657	0	0
	1665	1	22½ West
	1666	1	35 : 36
By Halley . . .	1672	2	30
	1683	4	30
	1692	6	0
	1700	8	0
By Graham . . .	1722, March 8	14	22"

X.

"*Observations of Magnetic Declination made at Berlin, by Kirche.*[2]

Year.		Month.	Declination.
1717	:	June	10° 42′
	:	26 Nov.	10° 55′
1724	:	13 Aug.	11° 45′
1725	:	14 June	10° 56′"

[1] Musschenbroek, p. 154, except last item, which is added from p. 123. —*Trs.*

[2] *Ibid.*, 155.

XI.

"*Declinations taken in the Baltic* (Philosophical Transactions, *vol. xxxi. p.* 120).[1]

	Latitude North.	Declination West.
At Revell, in 1720	58° 58′	14° 53′
At Gothland, 1720	58° 21′	14° 50′
At Bornholm, 1720	56° 0′	14° 44′
(In the year 1730, during the month of October, I took the declination at Salberg, or at the Silver Mine of Sahla, where the latitude is 60°, and the longitude 16° 17′ east from London : the declination was)		(9° 30′)"

XII.

"*A Table, containing the Magnetic Declinations as observed in four voyages to Hudson's Bay, from* 1721 *to* 1725 ; *extracted from the* Philosophical Transactions, *vol. xxxiv. pp.* 73-76.[2]

Latitude.		Longitude from London.		Variation.		Latitude.		Longitude from London.		Variation.	
Deg.	Min.	Deg.	Min.	Deg.	Min.	Deg.	Min.	Deg.	Min.	Deg.	Min.
50	0	12	0	14	0	53	0	14	15	15	45
51	0	12	0	14	15	54	0	14	15	16	0
52	0	12	0	14	30	55	0	14	15	16	15
53	0	12	0	14	45	56	0	14	15	16	30
54	0	12	0	15	0	57	0	14	15	16	45
55	0	12	0	15	15	58	0	14	15	17	0
56	0	12	0	15	30	59	0	14	15	17	15
57	0	12	0	15	45						
58	0	12	0	16	0	50	0	16	30	16	0
59	0	12	0	16	15	51	0	16	30	16	15
						52	0	16	30	16	30
50	0	14	15	15	0	53	0	16	30	16	45
51	0	14	15	15	15	54	0	16	30	17	0
52	0	14	15	15	30	55	0	16	30	17	15

[1] Musschenbrock, p. 160. The declinations were taken by William Sanderson.
[2] *Ibid.*, pp. 161-165. The declinations were observed by Christopher Middleton.—*Trs.*

Latitude. Deg.	Latitude. Min.	Longitude from London. Deg.	Longitude from London. Min.	Variation. Deg.	Variation. Min.
56	0	16	30	17	30
57	0	16	30	17	45
58	0	16	30	18	0
59	0	16	30	18	15
50	0	18	45	17	0
51	0	18	45	17	15
52	0	The same		17	30
53	0	throughout		17	45
54	0			18	0
55	0			18	15
56	0			18	30
57	0			18	45
58	0			19	0
59	0			19	15
50	0	21	0	18	0
51	0	21	0	18	15
52	0	21	0	18	30
53	0	The same		18	45
54	0	throughout		19	0
55	0			19	15
56	0			19	30
57	0			19	45
58	0			20	0
59	0			20	15
50	0	23	15	19	0
51	0	The same		19	15
52	0	throughout		19	30
53	0			19	45
54	0			20	0
55	0			20	15
56	0			20	30
57	0			20	54
58	0			21	0
59	0			21	15
50	0	25	30	20	0
51	0	The same		20	15
52	0	throughout		20	30
53	0			20	45
54	0			21	0
55	0			21	15
56	0			21	30
57	0			21	45
58	0			22	0
59	0			22	15
50	0	27	45	21	0
51	0	The same		21	15
52	0	throughout		21	30
53	0			21	45
54	0			22	0
55	0			22	15
56	0			22	30
57	0			22	45
58	0			23	0
59	0			23	50
50	0	30	0	22	0
51	0	The same		22	15
52	0	throughout		22	30
53	0			22	45
54	0			23	0
55	0			23	15
56	0			23	30
57	0			23	45

Latitude. Deg.	Latitude. Min.	Longitude from London. Deg.	Longitude from London. Min.	Variation. Deg.	Variation. Min.
58	0			24	0
59	0			24	15

Latitude. Deg.	Latitude. Min.	Longitude from London. Deg.	Longitude from London. Min.	Variation. Deg.	Variation. Min.
50	0	32	15	23	0
51	0	The same		23	15
52	0	throughout		23	30
53	0			23	45
54	0			24	0
55	0			24	15
56	0			24	30
57	0			24	45
58	0			25	0
59	0			25	15

Latitude. Deg.	Latitude. Min.	Longitude from London. Deg.	Longitude from London. Min.	Variation. Deg.	Variation. Min.
50	0	34	30	24	0
51	0	The same		24	15
52	0	throughout		24	30
53	0			24	45
54	0			25	0
55	0			25	15
56	0			25	30
57	0			25	45
58	0			26	0
59	0			26	15

Latitude. Deg.	Latitude. Min.	Longitude from London. Deg.	Longitude from London. Min.	Variation. Deg.	Variation. Min.
50	0	36	45	25	0
51	0	The same		25	15
52	0	throughout		25	30
53	0			25	45
54	0			26	0
55	0			26	15
56	0			26	30
57	0			26	45
58	0			27	0
59	0			27	15

Latitude. Deg.	Latitude. Min.	Longitude from London. Deg.	Longitude from London. Min.	Variation Deg.	Variation Min.
50	0	39	0	26	0
51	0	The same		26	15
52	0	throughout		26	30
53	0			26	45
54	0			27	0
55	0			27	15
56	0			27	30
57	0			27	45
58	0			28	0
59	0			28	15

Latitude. Deg.	Latitude. Min.	Longitude from London. Deg.	Longitude from London. Min.	Variation Deg.	Variation Min.
50	0	41	15	27	0
51	0	The same		27	15
52	0	throughout		27	30
53	0			27	45
54	0			28	0
55	0			28	15
56	0			28	30
57	0			28	45
58	0			29	0
59	0			29	15

Latitude. Deg.	Latitude. Min.	Longitude from London. Deg.	Longitude from London. Min.	Variation Deg.	Variation Min.
50	0	43	30	28	0
51	0	The same		28	15
52	0	throughout		28	30
53	0			28	45
54	0			29	0
55	0			29	15
56	0			29	30
57	0			29	45
58	0			30	0
59	0			30	15

Latitude. Deg.	Min.	Longitude from London. Deg.	Min.	Variation. Deg.	Min.
51	0	46	0	29	0
52	0	The same		29	15
53	0	throughout		29	30
54	0			29	45
55	0			30	0
56	0			30	15
57	0			30	30
58	0			30	45
59	0			31	0
52	0	48	30	30	0
53	0	The same		30	15
54	0	throughout		30	30
55	0			30	45
56	0			31	0
57	0			31	15
58	0			31	30
59	0			31	45
53	0	51	0	31	0
54	0	The same		31	15
55	0	throughout		31	30
56	0			31	45
57	0			32	0
58	0			32	15
59	0			32	30
60	0			32	45
54	0	54	0	32	0
55	0	The same		32	15
56	0	throughout		32	30
57	0			32	45
58	0			33	0
59	0			33	15
60	0			33	30
61	0			33	45

Latitude. Deg.	Min.	Longitude from London. Deg.	Min.	Variation. Deg.	Min.
54	0	57	0	33	0
55	0	The same		33	15
56	0	throughout		33	30
57	0			33	45
58	0			34	0
59	0			34	30
60	0			35	0
61	0			35	30
55	0	60	0	34	0
56	0	The same		34	30
57	0	throughout		35	0
58	0			35	30
59	0			36	0
60	0			36	30
61	0			37	0
57	0	63	0	35	0
58	0	The same		35	30
59	0	throughout		36	0
60	0			36	30
61	0			37	0
62	0			37	30
59	0	66	0	37	0
60	0	The same		37	40
61	0	throughout		38	20
62	0			39	0
63	0			39	40
60	0	69	0	41	0
61	0	69	0	41	40
62	0	69	0	42	20
60	0	72	0	40	0
61	0	72	0	42	0
61	40	72	0	42	40

Latitude. Deg.	Latitude. Min.	Longitude from London. Deg.	Longitude from London. Min.	Variation. Deg.	Variation. Min.
62	0	78	0	43	0
63	0	78	0	44	0
63	50	78	0	46	0
61	0	75	0	38	0
62	0	75	0	43	0
62	50	75	0	45	0
63	0	81	0	43	0
64	0	81	0	46	0
62	0	82	0	39	0
63	0	82	0	44	0
61	0	84	0	33	45
62	0	84	0	40	0
63	0	84	0	42	0

Latitude. Deg.	Latitude. Min.	Longitude from London. Deg.	Longitude from London. Min.	Variation. Deg.	Variation. Min.
60	0	86	0	30	0
61	0	86	0	33	0
62	0	86	0	35	0
59	0	88	0	28	0
60	0	88	0	28	40
61	0	88	0	29	20
57	0	90	0	24	0
58	0	90	0	24	30
59	0	90	0	25	0
57	0	94	0	23	0
58	0	95	0	22	30
59	0	95	0	21	0"

XIII.

"*Observations of the Declination of the Magnet, given in* Miscellanea Curiosa sive Ephemeridum Medico-physicarum Germanicarum Academiæ Naturæ Curiosorum, *decuriæ ii. annus ii. anni* 1683. *Norimbergæ,* 1684 (*p.* 446)*; the first meridian drawn through the Island of Teneriffe; for the year* 1675*; taken by Leydekker.*[1]

The Day of the Year. April.	Latitude. Deg.	Latitude. Min.		Longitude. Deg.	Longitude. Min.	Longitude. Sec.	Declination East. Deg.	Declination East. Min.
1675, 12	0	20	North	358	0	0	1	36
22	4	25	South				2	3
23	5	55		357	31	15	3	48
24	7	23					4	0
25	8	40					4	15
26	9	52		356	51	30	4	30
27	11	26					4	48
28	13			356	33	45	4	15
29	14	13		356	20	30	5	52

[1] Musschenbroek, pp. 170-171.—*Trs.*

The Day of the Year.	Latitude.		Longitude.			Declination East.	
June.	Deg.	Min.	Deg.	Min.	Sec.	Deg.	Min.
30	15	14 South				6	30
May 2	17	8	356	1	45	6	37
8	25	36	352	5	55	11	55
15	34	26	2	50	0	11	15
17	34	14	7	23	15	7	30
21	35	30	15	2	0	4	2
23	36	8	18	47	15	3	28
						West	
26	35	15	25	58	15	0	48
27	34	42	27	33	0	2	8
29	34	9	32	52	45	5	28
30	33	46	36	40	0	7	30
June 20	36	35	39	20	0	—	—
22	38	25	41	14	0	11	30
25	—	—	50	20	0	16	0
28	37	28	57	50	0	20	40
29	37	49	60	0	0	21	45
30	38	3	62	4	15	23	0
July 5	37	33	77	25	30	26	30
6	37	45	80	18	0	26	45
7	—	—	82	0	0	25	44
9	38	14	87	25	45	25	30
10	—	—	—	—	—	22	22
12	38	3	96	20	0	22	44
13	37	1	98	0	0	21	30
15	35	54	103	0	0	18	40
19	28	46	111	36	30	10	3
21	26	50	—	—	—	7	54
22	25	22	116	17	45	7	30
23	23	30	—	—	—	7	0
25	20	26	118	43	0	6	40
29	14	10	122	6	0	4	15
30	12	0	122	12	15	3	45
31	11	28	122	30	0	2	0
August 1	9	0	123	1	45	2	10"

XIV.

"*Magnetic Declinations observed in the year* 1708, *by Feüillée on a voyage to America.*[1]

Latitude. Deg.	Min.	Longitude. Deg.	Min.	Declination. Deg.	Min.
		Cagliari in Sardinia		10	19 West
35	35 North	Malta		10	25
39	54	Port Mahon		10	26
5	49	354	52	0	7
5	24	357	3	0	0
Under the equator		354	0	0	37 East
2	26 South	353	3	1	5
8	4	352	39	1	17
13	3	351	46	3	32
20	21	350	27	8	11
21	10	349	21	8	4
21	53	348	8	7	46
22	8	347	25	9	8
22	20½	346	58½	9	28
22	44½	346	6½	9	0
27	5	355	52	12	17
28	55	331	21	12	0
31	0	329	7	16	24
34	18	327	49	18	17
41	11	322	46	19	19
42	16	322	15	17	57
43	24	321	49	19	57
46	24	319	44	19	16
53	0	315	29	23	5
55	45½	318	9	23	3½
51	26	299	29	15	0
49	51½	299	54	13	30
41	4	303	20	11	33
33	1	Valparaiso		9	30
13	9½	Lima		6	15"

[1] Feüillée's *Journal des Observations physiques.* Paris, 1714, vol. i. *passim.* Quoted here from Musschenbroek, pp. 185-186.—*Trs.*

XV.

"*Variations observed in the Great South Sea, from the South Cape of California to the Island of Guam or Guana, one of the Ladrones; from the* Philosophical Transactions (*vol. xxxi.* p. 174)*; the meridian passing through London; for the years* 1709 *and* 1710.[1]

Latitude. Deg.	Latitude. Min.	Longitude West. Deg.	Longitude West. Min.	Declin. East. Deg.	Declin. East. Min.	Latitude. Deg.	Latitude. Min.	Longitude West. Deg.	Longitude West. Min.	Declin. East. Deg.	Declin. East. Min.
22	16	114	9	3	0	13	25	160	31	2	50
21	18	114	42	2	50	13	41	163	0	3	0
20	24	115	15	2	50	13	41	165	18	3	20
19	25	115	45	2	50	13	44	167	26	3	30
18	56	116	24	2	45	13	36	169	56	3	45
18	0	117	6	2	45	13	33	172	27	4	0
17	11	117	30	2	15	13	36	175	0	4	30
16	32	118	5	2	0	13	32	177	21	5	20
15	44	118	54	1	50	13	40	179	28	6	30
15	0	120	15	1	30	13	47	181	24	7	0
14	49	122	5	1	10	13	54	183	22	7	30
14	36	124	25	0	50	13	52	185	37	9	0
14	24	126	45	0	40	13	40	187	42	10	15
14	14	129	5	0	45	13	28	189	49	11	0
13	50	131	23	0	50	13	21	191	30	11	30
13	29	132	58	1	0	13	12	193	25	12	0
13	29	134	41	1	10	13	7	194	37	11	50
13	22	136	48	1	15	13	10	195	51	11	0
13	27	139	21	1	25	13	3	197	51	10	0
13	32	142	7	1	30	13	0	199	3	9	50
13	32	144	37	1	40	12	57	200	16	9	30
13	36	147	32	1	50	12	54	202	20	9	0
13	26	150	18	2	0	12	58	204	12	8	40
13	26	153	2	2	10	13	4	206	6	8	20
13	26	155	19	2	25	13	5	207	33	8	0
13	26	157	43	2	30	13	5	209	4	7	50

[1] Musschenbroek, pp. 187-188. The variations were observed by Captain W. Rogers.—*Trs.*

Latitude.		Longitude West.		Declin. East.		Latitude.		Longitude West.		Declin. East.	
Deg.	Min.	Deg.	Min.	Deg.	Min.	Deg.	Min.	Deg.	Min.	Deg.	Min.
13	2	211	54	7	30	13	8	217	11	6	30
13	7	212	42	7	10	13	16	218	27	5	40
13	7	214	7	7	0	Island of Guana in sight."					
13	3	215	28	6	50						

XVI.

"*Declinations of the Magnet observed by Noël, on a voyage to the East Indies, in the year* 1706.[1]

Latitude.		Longitude.	Declination.	
Deg.	Min.		Deg.	Min.
—	—	At Lisbon . . .	6	30 West
18	20 North	50 miles from Cape Verd . .	1	15
14	0	A little nearer Cape Verd . .	0	0
4	—	2 deg. from the Ferro Islands, west .	0	0
0	0	3 deg. from the Ferro Islands, west	1	30 East
7	28 South	150 miles from Brazil . . .	3	0
11	20	In the same longitude . . .	4	0
15	15	In the same longitude . . .	4	45
25	40	700 miles from the Cape of Good Hope	3	20
27	10	600 miles from the Cape of Good Hope	2	30
31	45	360 miles from the same . .	0	0
33	48	250 miles from the same . .	4	0 West
35	10	In sight of the Cape of Good Hope	13	40
36	40	200 miles from the same Cape towards the east	18	30
35	40	250 miles from the same Cape towards the east	22	0
36	0	Under the meridian of the Island of Madagascar	36	0
34	44	600 miles from the Cape of Good Hope	22	0
30	40	800 miles from the same Cape .	20	0
28	15	On the same voyage towards the east	16	0
27	44	950 miles from the same Cape .	15	0
24	54	1200 miles from the same Cape .	10	0

[1] See François Noël's *Observationes Mathematicæ et Physicæ.* Pragæ, 1710, pp. 113-115. Quoted here from Musschenbroek, pp. 172-173.—*Trs.*

Latitude. Deg.	Min.	Longitude.	Declination. Deg.	Min.
23	8	1300 miles from the same . .	8	40 West
19	39 South	1450 miles from the same . .	6	0
14	37	In the vicinity of Borrapheliote .	2	40
4	20	30 miles from Sumatra . . .	0	0
2	40	Under the meridian of the City of Acheen in that Island . .	1	30
0	0	Under the meridian of Bengal .	3	0
4	50	Between the meridian of the proceeding and Ceylon	4	0
7	50	Near Batcola in Ceylon . .	4	0
9	0	On the shore of the City of Cochin .	6	20
13	30	Near the City of Goa . . .	6	40"

XVII.

"*In the year* 1708, *on a voyage in the Sea of Sunda, towards Brazil.*[1]

Latitude. Deg.	Min.	Longitude.	Declination. Deg.	Min.
10	15 South	100 miles from the Sea of Sunda .	3	0 West
13	50	180 miles from the former place .	4	20
16	0	80 miles from the last place . .	7	0
18	48	144 miles from the last place .	9	0
21	4	120 miles from that last place .	11	20
22	8	40 miles from the last place . .	11	20
24	8	100 miles from the last place .	16	50
26	27	80 miles from the last place . .	19	20
28	47	124 miles from the last place .	24	0
30	12	86 miles from the last place . .	26	16
30	30	70 miles from the last place . .	24	30
31	0	23 miles from the last place . .	23	0
33	21	100 miles from the last place .	20	0
35	30	180 miles from the last place .	15	40
34	50	70 miles from the last place, that is, towards the Cape of Good Hope	14	0

[1] See Noël's *Observationes*, pp. 115-116. Quoted here from Musschenbroek, pp. 174-175. Noël gives these observations as made in 1708; Musschenbroek misprints this "1718," and Swedenborg copied the error.—*Trs.*

Latitude. Deg.	Min.	Longitude.	Declination. Deg.	Min.
34	45 South	70 miles from the Cape towards Brazil	11	0 West
30	4	139 miles from the last place .	4	30
18	57	250 miles from the last place .	2	0 East
13	30	320 miles from the last place .	6	0
13	10	Near the port of Boha in Brazil	11	30"

XVIII.

"*The Variation of the Compass, or Magnetic Needle, in the Atlantic and Ethiopic Oceans,* A.D. 1706; *in the* Philosophical Transactions (*vol. xxv. p.* 2433); *the first meridian passes through London.*[1]

Latitude. Deg.	Min.	Longitude. Deg.	Min.	Declination. Deg.	Min.
49	18 North	7	29 West	8	32 West
44	31	13	45	6	42
41	6	15	8	5	30
40	22	14	54	5	4
39	11	15	35	4	22
32	21	15	39	3	30
32	42	15	38	3	35
18	50	20	52	1	20
9	26	17	59	1	14
0	49	18	42	1	10
1	9 South	18	58	1	0
2	32	19	48	0	16
3	17	20	5	0	0
3	58	20	27	0	40 East
5	9	21	39	1	2
6	21	22	8	1	30
8	3	23	15	1	50
9	7	23	35	2	10
12	3	25	3	3	32
18	53	26	30	6	4

[1] Musschenbroek, pp. 175-176. The variations are given by John Maxwell, —*Trs.*

Latitude. Deg.	Min.		Longitude. Deg.	Min.		Declination. Deg.	Min.	
19	51	South	27	2	West	6	19	East
21	26		28	14		6	20	
21	48		28	10		6	30	
21	58		28	23		7	0	
24	45		27	56		6	45	
27	11		27	17		6	36	
33	53		16	58		5	4	
34	21		1	29 30″		0	0	
34	15		1	33	East	1	0	West
33	41		6	23		4	16	
34	39		13	2		8	46	
34	30		16	15	At the Cape of Good Hope	11	56	
32	51		13	41		11	30	
30	21		11	46		10	0	
29	51		11	44		9	44	
29	28		11	31		9	34	
28	56		11	5		9	22	
27	38		10	1		9	4	
26	55		8	45		8	30	
25	41		7	22		8	2	
24	32		5	43		7	32	
16	0		6	30	West; at the Isle of St Helena	1	52 ”	

XIX.

"*Magnetic Declinations observed in the year* 1703 *given in the* Histoire de l'Académie Royale des Sciences, année 1705, *Mem.* (*pp.* 9-10) ; *the first meridian passes through the Ferro Islands.*[1]

Latitude. Deg.	Min.		Longitude. Deg.	Min.	Declination. Deg.	Min.	
5	40	North	358	0	1	30	West
5	20	South	356	—	1	0	East
11	15		352	40	1	30	
21	0		350	0	6	30	

[1] Musschenbroek, p. 177. The declinations were given by G. D. Cassini in the *Histoire.*—*Trs.*

Latitude. Deg.	Min.	Longitude. Deg.	Min.	Declination. Deg.	Min.
34	40 South	7	45	3	15 East
36	0	24	10	3	0 West
36	20	41	0	13	0
35	35	53	30	19	0
32	50	69	0	25	30
28	0	98	30	19	0
22	40	96	35	15	0
1	20	106	40	4	0
14	40	105	20	4	45 "

XX.

" *A Table of Magnetic Declinations made by Commander Houssaye, in the years* 1704 *and* 1705 *: the first meridian passing through the Peak of Teneriffe : given in the* Histoire de l'Académie Royale des Sciences, année 1708, *Mem.* (*p.* 174).[1]

Latitude. Deg.	Min.	Longitude.	Declination. Deg.	Min.
—	—	The place, Port Louis, France	5	0 West
22	0 North	357° 0′	0	0
16	30 South	353° 45′	2	30 East
18	0	354° 0′	3	30
23	0	354° 0′	3	30
—	—	The same	11	0 A.D.1682
28	0	357° 0′	6	0
—	—	In sight of the Cape of Good Hope	9 to 10 West	
—	—	The western part of the Needle's Bank	12	0
—	—	The eastern part . . .	13	30 to 14
—	—	The Cape of Good Hope	7 to 7	30 A.D 1680
—	—	The Mozambique Channel .	22 to 23	
—	—	In 1711, Kolbe observed the declination here to be .	11	55
—	—	To the Bay of St Augustin	less than	21¾ A.D.1704

[1] Musschenbroek, pp. 177-179.—*Trs.*

Latitude. Deg.	Min.		Longitude.	Declination. Deg.	Min.	
—	—	South	In sight of the Island of Jean de Nova	22	0	West
—	—		In sight of the Mayotte Islands, Amzuam and Moely .	20	30	
0	0		70° 0′	16	0	
15	0	North	87° 0′	10	30	
16	30		In sight of Canara, and along Malabar . . .	6	30	
—	—		At Cape Comorin . .	7	30	
—	—		In Ceylon, at point de Galle .	5	30	
—	—		Near Coromandel . .	5	0	
—	—		Near the Andaman and Nicobar Islands . . .	3	0	
—	—		In sight of the Island of Diego Roiz	16	30	
—	—		In sight of the Mauritius .	21	0	
—	—		In sight of the Island of Bourbon	21	30 to 2 22	
25	0	South	74° 0′	23	30	
27	15		72° 45′	24	30	
33	10		65° 45′	24	30	
—	—		The Island of St Helena .	1	0	
—	—		The Island of Ascension .	0 or 1		East
0	0		357° to 358° . . .	0	0	
—	—		In sight of the Island of Corvo Flores . . .	4 to 4	30	West
—	—		At Newfoundland . .	7 or 8		
—	—		Coast of Britain . . .	5	0"	

XXI.

"*A Table of Magnetic Declination, given by J. N. de Lisle in the* Histoire de l'Académie Royale des Sciences, année 1710, *Mem.* (*p.* 354); *the meridian passing through the Peak of Teneriffe.*[1]

Latitude. Deg.	Min.		Longitude.	Declination. Deg.	Min.	
44	45	North	120 leagues from the French coast, A.D. 1708 and 1709 . .	8	0	West
45	7		11° 31′	6	40	

[1] Musschenbroek, pp. 179-180.—*Trs.*

Latitude. Deg.	Min.		Longitude.	Declination. Deg.	Min.
45	20	North	358° 15′	11	0 West
35	35		0° 0′, A.D. 1708	4	35
27	58		353° 40′	4	32
36	0		325° 46′	5	8
46	50		From Rochelle 230 leagues, 1709 .	7	50
33	45		5° 0′	6	0
43	45		340° 46′	13	0
44	45		52 leagues from Cape Finisterre, 1707	7	20
—	—		In sailing 60 leagues to the west .	7	20
7	15	South	1° 50′	2	30
—	—		Roads of Juda, coast of Guinea, 1708	8	20
—	—		——— 1705	8	0
—	—		St Thomas	11	30
28	30	North	316° 30′, 1709	1	30
32	15		321° 45′	4	10
36	50		329° 0′	7	10
45	8		305° 30′	10	10"

If these observations have been well taken, then, according to Musschenbroek, at the parallel of 22 degrees south latitude, the line void of magnetic declination would have moved westward 120 miles from the year 1700 to 1708.

XXII.

" *A Table of Observations of the Variation of the Compass, in the Ethiopic Ocean, in the year* 1721 [*and the beginning of* 1722, *by Captain Cornwall*] ; *from the* Philosophical Transactions (*vol. xxxii. p.* 55) ; *the meridian distance being reckoned from St Jago.*[1]

Latitude. Deg.	Min.		Meridian Distance. Deg.	Min.		Longitude. Deg.	Min.		Declination Deg.	Min.	
9	8	South	9	23	West	9	25	West	2	13	East
11	12		10	46		10	5		4	30	
11	34		11	28		11	41		4	29	

[1] Musschenbroek, pp. 180-181.—*Trs.*

Latitude. Deg.	Min.	Meridian Distance. Deg.	Min.	Longitude. Deg.	Min.	Declination. Deg.	Min.
12	32 South	11	31 West	11	43 West	4	27 East
15	46	10	53	11	6	6	10
16	26	8	25	8	30	7	16
18	45	9	31	9	39	6	17
19	47	9	10	10	0	8	6
28	43	1	7	1	9 East	5	53
31	33	3	41 East	3	56	4	10
33	30	11	29	12	57	0	11 West
32	40	19	6	12	1	3	0
32	53	21	18	24	59	5	41
32	30	25	33	30	0	7	47
32	28	30	37	35	52	8	44
31	22	31	40	37	7	10	57
31	11	32	4	37	47	11	20"

XXIII.

"*Observations on the coast of Africa, in the years* 1721 [*and* 1722], *extracted from the* Philosophical Transactions (*vol. xxxii. p.* 56).[1]

Latitude. Deg.	Min.	Meridian Distance.		Longitude.		Declination. Deg.	Min.
26	17 South	35	35 East	41°	41′ East	14	30 West
19	41					12	22
17	4					14	29
13	56					14	48
10	57					13	11
8	19					15	14
5	0	In Cabenda Bay				14	33
		From Cabenda to London					
3	25	11	38 West	11	43 West	11	32
3	30	21	18	21	24	—	—
0	30	30	41	30	46	1	5
10	50 North	39	8	39	16	1	1 East
17	15	43	21	43	29	1	41"

[1] Musschenbroek, p. 181.—*Trs.*

XXIV.

"*Observations of Declinations taken in the year* 1706, *by Commande de la Verune, described in the* Histoire de l'Académie Royale des Sciences, année 1708, *Mem.* (*p.* 295) *: in which the first meridian is reckoned through the Peak of Teneriffe.*[1]

Latitude. Deg.	Min.	Longitude.	Declination. Deg.	Min.
20	44 South	345° 44′ Near the Island of Ascension, 1706	7	30 East
56	6	297° 12′ Near the Island of Hermite, 1707	20	0
52	19	310° 30′ Sebald's Island . .	23	0
13	6	300° 10′ Near Point Canette . .	7	0
14	1	296° 27′ Near Pisco . . .	7	0
31	49	297° 30′ Valparaiso . . .	8	0
36	30	299° 25′ Near Conception . .	10	0
44	49	In these instances, a short distance from the western coast of America	12	0
48	58		13	0
53	37		15	0
56	42		17	0"

XXV.

"*Observations of Declinations collected from Dampier's* New Voyage round the World. *London*, 1703.[2]

Latitude.		Longitude.	Declination.
51°	25′ South	In the year 1683, in the Islands of Sebald de Waert [Falkland Islands	23° 10′ East
—	—	In 1707	23° 0′
47°	10′	In the Pacific Ocean, in 1683 . .	15° 30′
36°	0′	In the same	8° 80′ "

[1] Musschenbroek, p. 182.

[2] *Ibid.* p. 182. 1707 evidently from some other source.—*Trs.*

XXVI.

"*Observations of Declinations in the year* 1706, *described in the* Histoire de l'Académie Royale des Sciences, 1710, *Mem., p.* 358.[1]

Latitude. Deg.	Min.	Longitude.	Declination. Deg.	Min.
—	—	25 leagues from Porto Santo near Madeira	5	0 West
—	—	Near Madeira	4	30
—	—	But at the S.W. between Madeira and the Island of Ferro . .	4	0
—	—	50 leagues towards S.S.W. from the Island of Ferro . . .	3	0
18	15 North	357° 0′	2	30
—	—	Between the former place and the Bank of Bisagos on the coast of Guinea, the declination is constantly observed to be . .	2	30
6	0	358° 0′	2	0
3	15	0° 10′	2	0
0	0	7° 0′	2	0
—	—	But 50 leagues further on, S.E. .	3	0
—	—	And 50 leagues further on . .	4 to 5	
9	0	356° 15′	5	0
—	—	And 50 leagues further towards the S.W.	5 to 4	
—	—	50 leagues further in the same direction	4 to 3	
—	—	50 leagues further in the same direction	2 to 1	
—	—	Whence after sailing 250 leagues .	0	0
—	—	50 leagues further . . .	1	0 East
—	—	20 leagues N.E. from the Island of Ascension	6	0
—	—	The Island of Grande, off Brazil .	11	40
—	—	The Straits of Magellan . .	12	0
—	—		13	0
—	—		16	0
—	—		17	0

[1] Musschenbroek, pp. 183-185.—*Trs.*

Latitude. Deg.	Min.	Longitude.	Declination. Deg.	Min.
—	—		18	0 East
—	—		19	0
40	30 South		19	30
—	—	The same declination remains under the same latitude for 60 leagues	19	0
57	10	60 leagues S.W. from the Straits of Maire	26	0
57	40	For 40 leagues	26	0
—	—	Conception	9	30
—	—	Pisco	8	0
—	—	Canette	6	30
—	—	Callao	6	0
44	45	30 leagues from Chili . . .	12	0
44	45	120 leagues from Chili . . .	7	0
40 & 41		10 leagues from the coast . .	9	0
40	41	130 leagues from the coast . .	6	0
30 & 31		60 leagues from the coast . .	7	0
30 & 31		220 leagues from the coast . .	5	0
—	—	In the year 1707, at the River Gallegue	23	0
—	—	60 leagues from Gallegue towards the Cape of Good Hope . .	22	0
—	—	30 leagues further . . .	20	8
—	—	150 leagues further . . .	18	0
—	—	110 leagues further . . .	16	0
—	—	150 leagues further . . .	14	0
—	—	60 leagues further . . .	13	0
—	—	50 leagues further . . .	12	0
—	—	20 leagues further . . .	11	0
—	—	30 leagues further . . .	10	0
—	—	20 leagues further . . .	8	0
—	—	100 leagues further . .	4	0
—	—	120 leagues further . . .	0	0
—	—	60 leagues further . . .	2	0 West
—	—	80 leagues further . . .	4	0
—	—	60 leagues further . . .	7	0
—	—	140 leagues further . . .	9	30

Latitude. Deg.	Min.	Longitude.	Declination. Deg.	Min.
—	—	60 leagues further towards the Cape of Good Hope . . .	8	0 West
33	30	530 leagues from the Cape of Good Hope towards the east . .	24	30 "

XXVII.

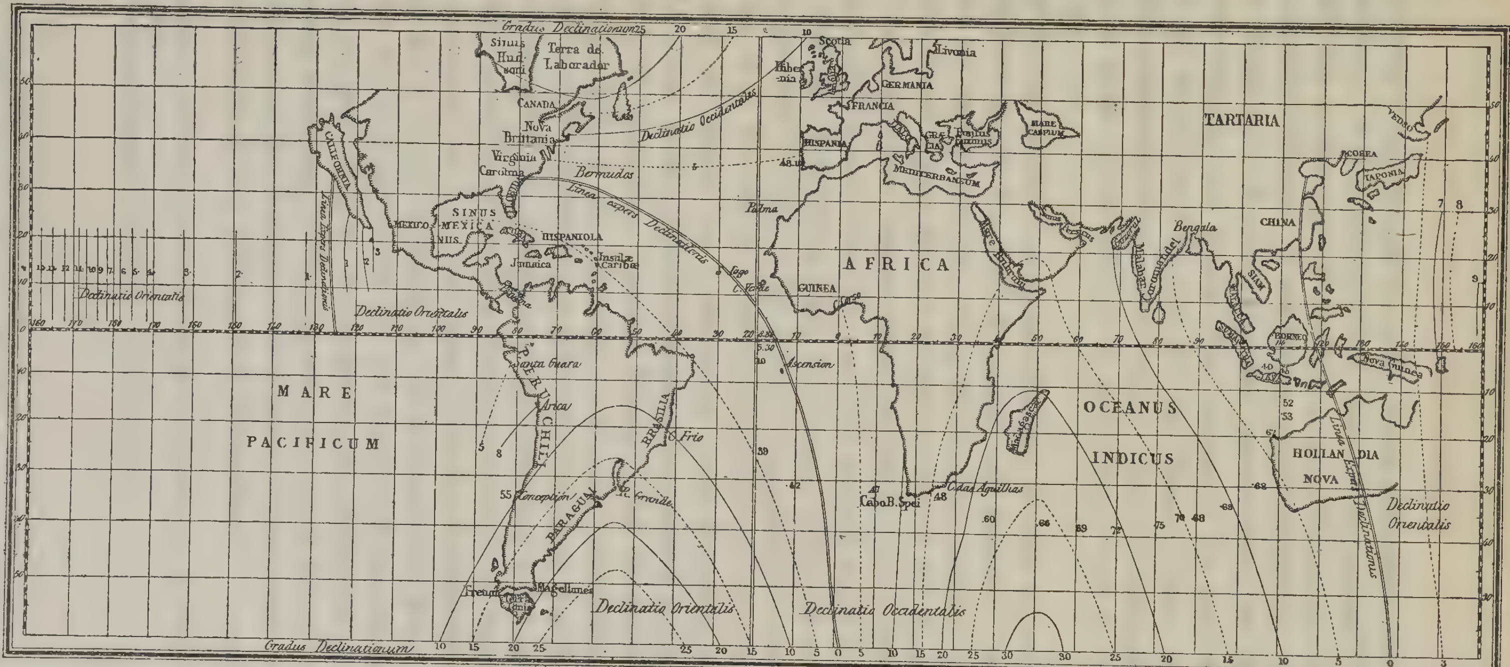
In the last place we have Halley's Map,[1] made up to the year 1700, and in which the declinations observed throughout the world are denoted by lines. Respecting this map, Musschenbroek remarks as follows :—

"From the rude chaos of observations, the sagacious and ingenious Halley has formed a kind of system, which although, as its philosophic author himself confesses, still imperfect, and subject to correction, is nevertheless confirmed more and more by the observations of every day. Hence we are bound to assume this system as a basis, following the example of the savants of the Royal Academy of Paris, who use it, compare it with fresh observations made in different voyages, and, rejecting all other hypotheses, correct, study, enlarge, and illustrate this alone. See the *Histoire de l'Académie Royale des Sciences*. 1712 (p. 17). In order, therefore, that this matter, intricate as it is, may be clearly comprehended, Halley's magnetic map must be laid open before us, and must be the basis of all our calculations. This map represents almost the whole world ; it also contains straight lines, exhibiting the meridians, drawn from the south pole to the north : it has also lines of latitude like those observed in common maps : and besides these, curved lines, which are for the purpose of showing the direction of the magnet. This map is prepared for the year 1700, when the declination of the magnet was such as is denoted in the places referred to. 1. There is a curve which begins in America, at Carolina, and passing through the Island of Bermuda, and through

[1] Halley's *General Chart ; showing at one view the variation of the Compass in all those seas with which the English Navigators were acquainted*, 1701.—*Trs.*

TABULA TOTIUS ORBIS TERRARUM.

EXHIBENS DECLINATIONES MAGNETICAS AD ANNUM 1700 COMPOSITA AB EDMUNDO HALLEYO SIMUL CUM INCLINATIONIBUS A POUNCLIO OBSERVATIS.



Newbery Litho.

p. 55),[1] made in the year 1721, it will be plain that these curves have receded toward the east: for under the latitude 32° 40′, and longitude 12° 1′, we observe a declination of 3 degrees only, where Halley makes it 7 or 8 degrees. In the same place under the south latitude 31° 32′ and longitude 37° 7′, is placed the declination 10° 57′, where Halley makes it nearly 20 degrees" (*op. cit.* pp. 167-168).

For further particulars we refer the reader to Musschenbroek.

[1] Reprinted above, at p. 49.—*Trs.*

CHAPTER XV.

ON THE CAUSES OF MAGNETIC DECLINATION.

In our former remarks upon first principles, it has been abundantly shown that there is a certain element, which controls the magnet, and the motion and arrangement of whose particles the magnet follows. This I have called the magnetic element; because we see its phenomena and natural mechanism more particularly in the case of magnets; although it acts also upon the particles of ether, air, and other elements, which could not subsist without an orderly sequence and series of smaller and greater particles; on this subject we have treated in another place. There is, therefore, a most subtle magnetic element rendered visible to us principally by magnetic experiments. The particles of this element are, according to principles already laid down, of two kinds; smaller and larger; the smaller subsist by a pure natural mechanism; the larger, which directly constitute the magnetic spheres, are both of themselves, and also by means of the smaller ones, held and preserved continually in their polar position. They cannot be disturbed by the particles of any other element, because these are denser, and so can act upon the magnetic particles only in a much grosser manner, and upon their volumes. Since every particle of this element, therefore, according to our principles, turns itself to the pole, and in company with those in its neighbourhood adheres to the poles; it follows, that all in one series take up a polar situation; that they maintain a parallelism in relation to one another; and consequently bring the spheres of the magnet into the same situation with themselves and also retain them in that position.

2. This magnetic element exists chiefly in the solar vortex, or that of our universe or mundane system. It also enters into the vortices of the planets and earth, within which move the satellites and moons. The surface of the earth, however, is occupied by air, and still more closely by water; but together with all the other elements there exists the magnetic element. The air, however, and water, do not penetrate into the expanse of the vortex, but are confined to the earth and its vicinity; because their particles, being denser and more concrete, are driven thither by the smaller, by a kind of centripetal force, of which we shall speak more at large in our theory of the tellurian vortex. The vortex, therefore, of our earth, for the most part, consists of particles of the magnetic element; for it is known that a vortex surrounds the earth, within which, like a nucleus, the earth revolves: or is enfolded as an infant in the arms of its nurse; and since the element of the world's vortex is carried round by a kind of spiral motion, it follows from our first principles that this vortex must, by reason of its spiral motion, form an ecliptic, although not a similar one, at every distance from the centre or from the earth; also that it must form poles; also that at the poles apertures will be formed resembling cones, by which the element can flow in and also flow out on the opposite side. These are the results of every spiral motion existing among moving elementary particles. For if we grant the existence of a vortical and spiral motion among particles constantly in a state of motion, we must grant the existence of a motion conformable to a greater circle, whether we call this circle an equator or an ecliptic. We must grant also, upon the geometrical principles of motion flowing into a helix or spire, the existence of poles, and also of apertures at the poles, and influx and efflux of the particles, without which there could be no continuous spiral motion. Moreover, particles of this kind have arisen and are adapted to the production of such a motion, for they possess this motion within themselves; in a word, the whole of their motion is vortical, according to the mechanism of their figure.

3. Since, therefore, there is without doubt a vortical and spiral

motion of particles in the vortex of our earth, and as ecliptics and poles are formed as a result, it follows that the element which quietly flows in at one pole and out at the other, has two poles, one on the south side of the earth, the other on its north side; and that from the south it pursues its course to the north, and so returns to its vortex, and repeats the course it before pursued. There are, therefore, two poles, one in the southern, and the other in the northern region.

Since, then, there are two poles, we may next enquire what is the distance of these from the poles of the earth or world. They cannot be identical with the poles of the earth, but are the same as the poles of the vortex. Since the vortex by its spiral motion forms ecliptics, so these poles must be identical with the poles of the ecliptic; that is to say, they will be at the same distance from the poles of the earth as the poles of the ecliptic, or 22° 30′. For if a vortex in its spiral motion forms real ecliptics from the outermost to the innermost part, there can be no other poles than those of the ecliptic; nor can there be any other magnetic poles than those of the ecliptic of the vortex; that is to say, they must be poles at a distance of 22° 30′ from the poles of the earth.

4. We are next to consider, that the influx of the particles of this element is at the south pole, and that it consequently tends to the north; not like a stream and torrent, but like a tranquil and peaceful current, which gradually and without any perceptible motion, pursues its course from one part to another. Nevertheless this force, small as it is, must be taken into consideration; for without it we shall by no means be enabled to arrive at the true knowledge of the declination.

5. Another point to be considered is, that this stream tends from the south pole to the north in a spiral manner; for it does not flow directly from one pole to the other, because it flows in spirally by polar cones, and embraces the surface of the earth by preserving the motion and pressure of a spire, until it comes to the other pole, or cone of emergence. For the motion begun is spiral, and cannot terminate rectilineally; especially when

it is received or taken up by a spiral motion in the north cone. This spire also must be taken into consideration in our calculation of the declination of the magnet.

6. That the poles themselves are in motion and perform a certain rotation within a certain time around the poles of the earth, although always at the same distance from them, is sufficiently evident from experiments. But both from experiment and from our first principles, which remain to be more especially explained in our theory of the vortex of the earth, it is evident that the north magnetic pole moves more quickly round the north pole of the earth, than the south magnetic pole round the south pole of the earth; for the reason that the distance of the two from the centre of the vortex is not the same, and because also of the spiral twist of the vortex. In the same theory we shall have to show that these magnetic poles move round the pole of the earth continually from west to east, and thus in a circle, but with unequal progress. But because both poles have not the same motion, they cannot return to their original position for several ages; nor can they do this until many ages have presented the same series of declinations. The north magnetic pole, which is distant from the north pole of the earth 22° 30′, completes its entire circle round the north pole of the earth within about 386 years, and this from west to east; or what amounts to the same, it progresses in its circle every year 56′. But the south magnetic pole, which is distant from the south pole of the earth 22° 30′, does not complete its circuit till within 1080 years, or progresses every year 20′ or the third part of a degree; so that the difference of motion in the poles is as 386 to 1080; or about 20 to 56. From which it follows, that the poles cannot return to their original position till after several circuits; that is to say, till after several ages; or until the north magnetic pole has completed 14 circuits, or the south pole 5; which it cannot do till the lapse of 5400 years.

7. But since the poles move from west to east around the poles of the earth, and always at the same distance from them; and since they cannot return to their original position for several

ages, we must ascertain the position of the poles in some given year, and from this we must then calculate their progression. This situation cannot be ascertained from any mere theory; for it is always different, and is every year changing; and, therefore, we must have recourse to experiment, which, after much labour and calculation, has taught me that in the year 1720 the north magnetic pole was distant westward from the London meridian 112°; that is to say, that in the year 1720, there was between the meridian passing through the pole, and the London meridian, an angle of about 112°; and that in the same year, 1720, the south magnetic pole was distant from the London meridian westward an angle of 145° 30′; that is to say, between the meridian passing from the pole of the earth through the magnetic pole and the London meridian there was an angle westward of 145° 30′. These angles can only be known from actual observation, which will confirm our foregoing remarks.

8. The situation of the magnet, or of the mariner's needle, when left to itself, will be similar to the situation of the magnetic element. For this element directs the sphere and at the same time the body of the magnet into a situation parallel with and similar to its own. Or more clearly thus: the arrangement of the particles of the magnetic element, is such as is the declination. For example; at Paris in the year 1727, the declination was observed to be 14° 0′ to the west, and in the same place the very particles of the element are turned at an angle of 14° from the north pole of the earth toward the west; and the same is the case with the needle.

The magnetic element itself does not appear to be able to act directly upon the needle or magnet, nor by any influx or efflux to direct it into that position; but it seems to act only upon the sphere by which the magnet or needle is surrounded, and urges it into a position parallel to itself; whence the sphere also urges the magnet or the needle in a similar way. This appears to be the true cause of the declination, as will be still more evident in the sequel.

The question is, therefore, what is the situation of the particles

of the magnetic element at any given place on the earth, and what is the reason why this situation is so different in one place from what it is in another; or what amounts to the same, what is the reason why the declination of the needle is so different all over the world. If this question receives a right solution, we shall then arrive at the true cause of the magnetic declination; for the latter question depends on the former.

We have shown above that there is a certain constant connection of particles of the magnetic element, extending from one pole to the other; and that one particle is bound, by reason of the mechanism of its figure, to follow another in an orderly sequence like a chain, from the beginning of its motion to the end. Since, therefore, the situation of the particles is thus regular, it follows in the first place, that in the circle which crosses directly from one pole to the other, the particles are disposed in agreement with this situation. Thus fig. 84, p. 5, let M be the north magnetic pole, and N the south magnetic pole. All the particles of the element which are in MN are in such a situation that one way they look to the north pole, another way to the south pole; that is to say, they conform to the tract or line of the circle MN; yet in respect to a different meridian, or the meridian through the poles of the earth, the arrangement cannot be polar or rectilinear in relation to this meridian; but must be different, so that a certain declination of the needle must necessarily appear.

Let us, however, enquire what occurs outside this circle in all other parts of the globe, and what arrangement of the particles of the magnetic element can be assigned upon mechanical principles, after it is known that there is a certain connection of particles extending from one pole to the other. If we consult the science of geometry, as in a case of this kind we unquestionably ought, we shall find that they cannot have any other position than such as corresponds to their distances on each side from the respective poles; and since there is a connection and a continual pressure of the particles from one pole to the other, the pressure at a less distance from the pole must be different from that at a greater distance, and contrariwise; there is, there-

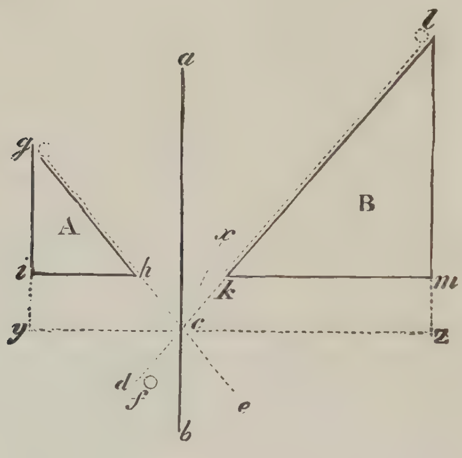
fore, an action upon the particles of this element according to the arcs or distances from the poles. But because there must be two ratios to form a proportion, so we find in the present state of the particles, no other proportion than that existing between the distances and angles; that is, as the distance or arc from one pole is to the distance or arc from the other pole, so is one angle to the other angle. We thus obtain the position of the particles in every place, provided there are given the distances or arcs from the poles, and the angles formed by each with a given meridian. Or what amounts to the same, as the sum of the arcs or sides is to the sum of the angles, so is one arc or one side to the required angle. This proportion follows geometrically from the connection and continual pressure of the particles. Since we have thus the arrangement of the particles, we have, consequently, the declination of the needle, which is the same with the position of the particles; as we have above observed.

In this manner the proportion of the sides and angles in the magnetic element may be shown. Every element exerts a pressure and acts proportionally to its height, as is the case with both water and air, and with all liquids; because one particle perfectly mobile and free pushes another equally and successively, just as all do simultaneously. Altitude in this magctic element can be conceived only as extending from one pole to the other; from the north magnetic pole to the south, and contrariwise. Nor can any other altitude be conceived as existing in this element; for it does not follow the law of a perpendicular as do water and air, since this element is not governed by any other; it has, therefore, no other element to force it into a perpendicular or horizontal position, or to keep it continually in a horizontal plane; for this element is the most attenuated of all, nor can any other act upon its particles, because every other is of a grosser nature.

Consequently, there cannot be any other altitude than the one pressing from pole to pole, nor any other pressure than that which acts vertically. In any given element there are two

altitudes, as well as two active forces, or two pressures; one pressure or force which comes from one altitude of the element, another which comes from another altitude of the same element, and each pressure acts according to its altitude. If these pressures or forces meet, then the direction which the fluid takes will be in the ratio of the altitudes and angles. Thus fig. 86, A and B are two oblique planes, the vertical of one being greater than that of the other; now if two little balls are allowed to fall down the planes, as in the larger, B, from *l* to *k*, then,

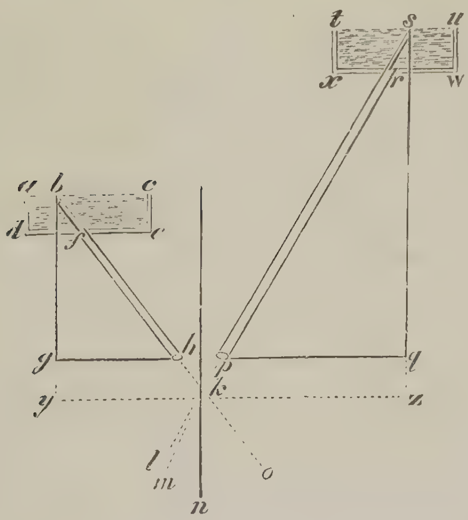
Fig. 86.



according to the given direction acquired from the plane, the ball will be carried toward *d*; unless by reason of its weight it begins to describe a parabola, which we do not propose to consider here; we merely deal with the natural and simple directions. Similarly the ball *g*, falling down the smaller plane to *h*, will tend in a right line to *e*. Suppose now these balls meet in *c* (or the one which fell from the altitude *l* meets the one which fell from the altitude *g*), it is required to know the direction taken by the larger after it has met the smaller; and the answer is, that, according to the common rule of mechanics, as the sum of the altitudes *gy* and *lz* is to the sum of the angles *gca* and *lca*, so will the altitude *gy* be to the angle *lcx*; or, which is the same

thing, the angle *dcf*. If therefore the required angle *dcf* be subtracted from the former angle *dcb*, we obtain the angle or the line along which the ball takes its direction, namely, the line *cf*. Instead of the altitudes we may take the hypothenuses *lkc* and *ghc*, if the triangles are similar. The reason is known from the foregoing remarks. The force of the descending ball increases with the altitude; therefore one ball descending from a higher altitude meets another with a force proportional to its

Fig. 87.



altitude; while the other ball descending from a smaller altitude acquires a force according to this altitude; therefore, when the two meet with their acquired forces, which are proportional to the altitudes, these forces will be to the directions as the altitudes to the angles.

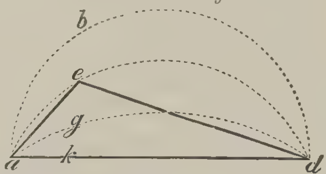
Instead of two balls let us take the case of water; for water is an element, and it is of the nature of an element that we treat. In fig. 87, let water be contained in *txuw* and at *adce*; let tubes *rp* and *fh* from these receptacles descend at an angle to a horizontal plane; the altitude of one is *sz*, the altitude of the other is *by*; therefore because the pressure of the water is ac-

cording to its altitude, let each stream be supposed to meet in k, it is required to know the direction taken by the water. The same ratio prevails here as in the former case. The force of the water is as its altitude; the pressure of each stream therefore is according to its altitude. The proportion is consequently as follows; as the sum of the altitudes or $sz+by$ is to the sum of the angles or $ski+bki$, so is the altitude by to the angle lkm; whence we obtain the direction of the water.

We have said that in the element of water, as also in air, these proportions are according to the altitudes; or that the pressure is according to the vertical height. Now if it is granted that the magnetic element exercises a pressure according to its altitude; that its altitude is to be estimated in the direction from one pole to the other; that each pole acts along its own side; why may not the altitude be conceived as along the axis or from one pole through the midst of the axis to the other? Why should the altitude be reckoned along circular lines or along the surface of the earth's figure, and not along its axis? In this case the altitude of the element we are considering would be similar to that of water and air, which passes directly along the axis from one pole to the other; it seems, therefore, as if the direction of the pressure ought to be calculated along the altitudes in the axis; or what amounts to the same, according to the sines of the circle and not according to its arcs. It is replied, however, that this magnetic element, conformably to the arrangement and connection of its particles, presses indeed according to its altitude, but not vertically like water and air, nor equally on all sides. For water and air press to the right and left, upwards, obliquely, and in every direction according to the depth; but the magnetic element cannot press according to its altitude laterally, but only in the direction of its flow. In this appears to consist the difference of the pressure between the magnetic element and water or air. The reason is, that one particle of this element is connected with another only in two places, namely, one at each pole; for, according to our prin-

ciples, as formerly laid down, every particle has its own poles. Since, therefore, one particle is connected with others only in two places, and the whole series thus coheres from one pole to another, it cannot act laterally or in other directions; it cannot act upon another along its equator, or through any other points of its figure or body. It acts, therefore, only in that direction in which it is capable of connection with the next pole; or in which it can exert pressure; thus it cannot act like water or air. Consequently, there can be a pressure and connection of the particles only in that direction, and only according to that altitude. Nor can there be any other altitude than the one according to which the particles are connected; that is to say according to the arcs of the surface of the earth. Therefore the altitude of the magnetic element is according to the circle of the surface of the earth, and its force according to the arc of distance from the poles. Hence it follows, fig. 88, if the magnetic element flow through the circle *abd*, that it exercises in *b* a pressure according to the arcs *ab* and *bd*; if it flows through another curve, as through *aed*, that it exercises in *e* a pressure according to the arcs *ae* and *ed*. The case is similar at *g*. If it flowed in a right line or along an axis such as *ad*, then at *k* it would press on both sides according to *ak* and *kd*. It may be asked still further, how it can be said that it exerts a pressure on both sides, and why there are, as it were, two altitudes and not one as in water. But because the north pole of one particle is conjoined in like manner with the south pole of the other particle, and the south pole of the former with the north pole of the latter; and because there is no difference between the conjunctions, a pressure on each side and an altitude on each side consequently follow.

Fig. 88.



Let the place where the declination is to be observed, be in *c* (fig. 89).[1] Let the meridian of this place be in *ah*; the north

[1] See sheet at end of this volume.

pole of the magnet in *b* ; the south pole in *g* ; the arc or distance of the place from one pole to the place of observation be *bc* ; the arc or distance from the other pole *cg* ; the angle of the meridian of the place of observation with the meridian of the south magnetic pole *gch*, or what is the same *acf*. Now in order to find the position of the particles of the magnetic element in this place, or what is the same, the declination, we must have recourse to the proportions thus furnished ; namely, as the sum of the sides ($bc+cg$) is to the sum of the angles ($bca+acf$), so is the side *bc* to the angle *xcb*. If this angle *xcb* be subtracted from the angle before given or *bca*, we obtain the angle of the position of the particles of the magnetic element, or the angle of declination *xca* ; and *xca* is thus the western declination of that place. A similar method is pursued in regard to any other place of observation ; as in figs. 95 and 96, in the meridian *ach* in respect to which the north magnetic pole is in *b* ; the south in *g* ; where we have a proportion similar to the former ; namely, as the sum of the sides ($bc+cg$), is to the sum of the angles ($bca+gch$), or what is the same, $bca+acf$, so is the side *bc* to the angle *bcx* ; and if this latter *bcx* be subtracted from the given angle *bca*, we obtain the eastern declination of the place. It sometimes happens that each angle is on the same side of the meridian ; in which case a similar method of proportion must be adopted, but instead of the sum of the angles we must take the difference, and instead of subtraction we must have recourse to addition, in order to obtain the declination. This, however, will be more clearly seen in the sequel.

We shall now proceed to explain the method of calculating the declinations of the magnet in different places of the earth, and at different periods. But because the calculation is tedious, and it is difficult at every stage in the several calculations to state the reasons of it and the diversities to which the calculation is subject, I have thought it better to give only a brief explanation of the particulars, and this, too, only in our first example ; but sufficient to enable us to prove the truth both practically and theoretically.

CHAPTER XVI.

CALCULATION OF THE DECLINATION OF THE MAGNET FOR THE YEAR 1722, AT LONDON.

Because the position of the poles in relation to the meridian of London for the year 1720 has been found by experiments, and the position of the north magnetic pole relatively to the north pole of the earth has been found to be 112° west, we have, consequently, first to add or subtract the angle between the London meridian and the meridian of the place where the declination is required. If the meridian of this place be distant from the London meridian 10° east, the angle must be added, thus; $112 + 10 = 122$; if it be distant 10° west, the angle must be subtracted, thus; $112 - 10 = 102$; for the meridian of the north magnetic pole is either near or remote, according to the nearness or remoteness of the meridian of the place of observation. Since, however, in our calculation we have assumed the meridian of London as our first meridian, there is in the present case no difference between the two meridians, and hence no necessity for any addition or subtraction.

We have next to ascertain the position of the north magnetic pole for the given year, whether in the past or the future; in the present case, for the year 1722; and since the annual progression of the north pole in its own circle is nearly 56′, hence $1722 - 1720 = 2$, or a difference of two years; and $2 \times 56' = 1° \ 52'$.

2. But since there is a progression of the north pole from west to east, we must take away 1° 52′ from the given angle; and thus we obtain the position of the pole for the required year, as follows; $112° - 1° \ 52' = 110° \ 8'$; whence the position of the pole in respect to the London meridian for that year is 110° 8′.

3. We have next to ascertain the situation of these poles in the meridian of the place or point of observation, or where an arc drawn from them cuts the meridian at right angles. Thus in fig. 92, where the north magnetic pole is in b and the north pole of the earth in a, we have to find where an arc from the former falls upon the meridian at right angles, as at zz fig. 92, for it is from this that we assume the terms for the subsequent calculations. We obtain then zza in the following trigonometrical manner. First, $110° 8' - 90° = 20° 8'$, which is the same with the angle $zzba$. Hence we obtain zza trigonometrically thus: as the radius or sine of $bzza$ is to the side ba, so is the sine of angle $abzz$ to the side zza; or as the radius is to $22° 30'$, so is $20° 8'$ to $zza = 7° 34'$. Or

Sine 22° 30′	9·58284
Sine 20° 8′	9·53682
	19·11966
Radius	10·00000
Sine 7° 34′	9·11966

4. When the point where the north pole thus falls into the meridian is found, that is, where the arc from it falls into the meridian at right angles, we may then easily ascertain the distance of this point in the meridian from the place of declination: for we have only to add zza to the complement of the latitude of this place; or to subtract it if it be in zz as in fig. 90, below the pole of the earth. Now since at London the altitude of the pole of the earth is $51° 32'$, its complement is $38° 28'$, which is equal to ac, fig. 92. Therefore zzc is equal to $38° 28' + 7° 34' = 46° 2'$.

5. The distance thus found, or zzc, is to be multiplied by $6''$; thus $6'' \times 46 = 4' \ 36''$. The reason of this calculation is, that as the magnetic element tends with a certain tacit current from the south pole to the north, its force is greatest at the south pole, and becomes gradually less toward the north, in the ratio of about one minute to every ten degrees, or six seconds to one

degree. We must, therefore, begin from the north pole and reckon toward the south. The greater the distance from the north pole, or the nearer to the south pole, the greater is the force; but toward the north pole it is less, and in the north pole itself it is only 22′ 30″. This addition or multiplication leads to the following calculations.

6. Since in the north pole there is a residuary force of 22′ 30″, obviously according to the distance of the magnetic poles from the poles of the earth, these minutes must be added to 22′ 30″. Thus $22' \ 30'' + 4' \ 36'' = 27' \ 6''$, which represents the force in the place *c*, viz., London in the year 1722.

7. We have next to ascertain the distance of the poles in the same meridian; which is done by addition if the magnetic poles are above the poles of the earth, but by subtraction if below them. In the present case the poles being above them, we have recourse to addition. The distance *zzyy* is required, fig. 92, and we obtain it thus: $zza + ah + hyy$ or $180° + 7° \ 34' + 18° \ 14' = 205° \ 48'$. In the sequel *hyy* will be seen to be equal to 18° 14′.

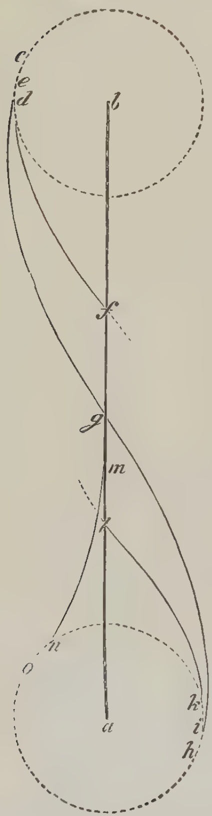
8. We must next proceed in a duplicate ratio. For instance, as the square of *ah* is to the square of *zzyy*, so are the minutes 27′ 6″ found in the point *b*, to the required number of minutes. Or, the square of 180 (=32,400) is to the square 205° 48′ (=42,400), as 27′ 6″ to 35′ 20″.

9. These minutes 35′ 20″ must be added to every ten degrees, beginning again from the north magnetic pole, or to every tenth degree of distance *zzc*; or must be multiplied by one-tenth; $35' \ 20'' \times \frac{46° \ 2'}{10} = 2° \ 42'$. We are thus supplied with the number 2° 42′ by which the distances of the poles and also the angles are to be diminished or increased, which is done partly on account of the force and current of the magnetic element from the south pole to the north, and partly on account of the spiral flow and pressure of this element.

10. The number 2° 42′ must now be added to the genuine side or true distance of the poles 22° 30′, so that this side which is to be used in our calculation, and which we, therefore, call the reduced distance, is $22° \ 30' + 2° \ 42' = 25° \ 12'$. For we

cannot reckon with the simple distance 22° 30′. If, however, there were no force tending from the one pole to the other and no tension or effort, nor any spiral figure in the flow, then we should simply use the distance 22° 30′. But as these anomalies disturb the calculation, so it cannot be carried on without the increase of the sides or distances in the way above mentioned. Thus the distance or other side for calculation may be found, which in the present case is 25° 12′, and this at each pole.

Fig. 97.



11. Because, however, the spiral flow of the element disturbs the angles, so that the pole cannot appear in its own true and natural place, but in some other by reason of the spiral twist, the angle requires to be varied and transposed. If, therefore, the north pole be in *c* (fig. 97), and the south in *h*, as the element flows spirally from one pole to another, near the pole the contorsion and twist of the spire is greater, and farther off it is less; consequently, if the pole be in *c* and the place of observation in *f*, the pole appears by reason of the spire to be in *d*, or in *k* if the place of observation be in *l*. As, therefore, the spire at the south pole runs from west to east, and at the north pole likewise toward the east, the degrees at the north pole must be taken away, or the angle diminished; and when this pole is in *c* it must be transposed to *d*. At the south pole, if it be in *h*, it must be transposed to *k*. Or if it be on the other side of the south pole, as in *n*, and the place of observation be in *m*, the angle of the pole must be transposed in the way we have mentioned from west to east, or from *n* to *o*, and so forth. Let the degrees found in the ninth clause, or 2° 42′, be first subtracted from the true angle in the second clause, namely, 110° 8′, and then there

remains the angle 107° 26′, which is the one to be adopted in the calculation, and which we, therefore, denominate the reduced angle, but which must be proportioned still further in a ratio to the distances from the pole.

12. Because, however, the nearer to the pole the greater is the twist of the spire, and the farther from the pole the less, the angle must again be subjected to another proportion, namely, to the distance from the pole; and hence I have prepared a table from which the proportions may be taken for every degree of latitude.

Lat. of the North or South Pole. Deg.	Proportions to be used in the Calculation. Deg.	Min.	Lat. of the North or South Pole. Deg.	Proportions to be used in the Calculation. Deg.	Min.
10	2	30	40	40	—
15	5	30	45	50	—
20	10	—	50	61	30
25	15	30	55	74	30
30	21	—	60	90	—
35	30	15	67 : 30′	112	30

This table is formed in the following manner. I assume as a basis 90, at which, or at a distance of 90° from the pole, the translation of the angles vanishes, and I have taken the least and greatest distance of the magnetic pole. Then I proceed in a duplicate ratio thus: since the least distance is 67° 30′ or $90° - 22°\ 30' = 67°\ 30'$, and the greatest distance 112° 30′ or $90° + 22°\ 30' = 112°\ 30'$, as the square of 67° 30′ or 4556° is to 112° 30′ so is the square of 10, 20, 30, 40, 50, 60, &c., to the number, $2\frac{1}{2}$, $5\frac{1}{2}$, 10, $15\frac{1}{2}$, 21, as found in the table. Since, therefore, the number 2° 42′ is already obtained by the multiplication of 60, or at a latitude of about 49, we must by a further proportion discover the other number, by which the angle formed by the north and south poles is diminished. The latitude of the pole at London is 51° 32′, and the number corresponding to this latitude is $66\frac{1}{2}$ or 67. We must then proceed thus: 60° : 67° : : 2° 42′ : 3° 1′. Thus 3° 1′ is the true number at this latitude

which is to be subtracted from the original angle at the north, which was 110° 8′. Hence 110° 8′ − 3° 1′ = 107° 7′. Whence the angle 107° 7′ is the reduced angle as changed from the former, or 110° 8′, and transposed in consequence of the spiral flow of the element.

We have thus the reduced distance at the north pole = 25° 11′; and the reduced angle at the same pole = 107° 7′, the supplement of which is 72° 53′.

13. These particulars being ascertained, we have next to find the sides and angles *bc* and *bca* (fig. 92).

We have first to find the side *dc*, which is done by the following process in spherical trigonometry. As the radius is to the sine *ac* (= 38° 28′ or the complement of the latitude), so is the sine *dac* (= 72° 53′ or the supplement of the angle of the meridians 107° 7′ to the semicircle) to the sine *dc* = 36° 28′. By logarithms thus;

Sine 38° 28′	9·79383
Sine 72° 53′	9·98032
	19·77415
Radius	10·00000
Sine 36° 28′	9·77415

The side *dc* therefore = 36° 28′. It is to be observed that the angle *ad* ought to be a right angle.

14. We next proceed to find the side *da* as follows. As the cotangent of *ac* (= 38° 28′) is to the whole sine, so is the cosine of *cad* (= 72° 53′) to the tangent *ad* (= 13° 10′). Trigonometrically thus;

Cosine	72° 53′	9·46881
Radius		10·00000
		19·46881
Cotangent	38° 28′	10·09991
Tang.	13° 10′	9·36890

Therefore *ad* is equal to 13° 10′.

15. We have next to find the side *bc* between the north magnetic pole and the place of observation. We have in the triangle *bdc* the two sides *bd* and *dc*, together with the included right angle *bdc*. But in order to obtain *bd*, we must add *ba* and *ad*. In the present case *ba* = 25° 12′, and is the same with the side of calculation, namely 25° 12′ + 13° 10′ = 38° 22′. Again *bc* is found thus. As the radius is to the sine of the complement *dc* (= 36° 28′), sö is the sine of the complement *db* (= 38° 22′) to the sine of the complement *bc* (= 50° 54′). Logarithmically thus;

Cosine	36° 28′	9·90536
Cosine	38° 22′	9·89434
		19·79970
Radius		10·00000
Cosine	50° 54′	9·79970

We have thus the side at the north, or *bc* = 50° 54′.

16. We have next to find the angle *bca*, which is done simply by means of the sines; for the three corresponding sines of the triangle *bac* are given. Thus as the sine *bc* (= 50° 54′) is to the sine *bac* (= 72° 53′ or the supplement of the angle 107° 7′), so is the sine *ba* (= 25° 12′) to the sine *bca* (= 31° 37′). Trigonometrically thus;

Sine 25° 12′	9·62918
Sine 72° 53′	9·98032
	19·60950
Sine 50° 54′	9·88988
Sine 31° 37′	9·71962

We have thus the angle *bca* = 31° 37′.

17. Let us now enquire as to the south pole, and similarly

ascertain the sides and angles there. In the first place must be added or subtracted the angle between the meridian of London and the meridian of the place where the declination is required. But because in our present calculation the first meridian is assumed to be at London, there is no difference of meridians, and, consequently, no need of addition or subtraction.

We have next to ascertain the position of the south magnetic pole for the given year, in the present case for the year 1722. Because the annual progression of the south pole in its own circle is nearly 20′, hence $1722 - 1720 = 2$, or there is a difference of two years, which multiplied by $20' = 40'$.

18. Because the progression of the south pole is from west to east, we are, therefore, to take away 40′ in order to arrive at the position of the pole for the required year 1722, which is done as follows: $145° \; 30' - 0° \; 40' = 144° \; 50'$. Hence the position of the pole in respect to the London meridian for that year is 144° 50′.

19. We have next to enquire into the position of the pole in the meridian of the place, or the point where an arc from it falls at right angles into the meridian, as in fig. 92. Let the south pole of the earth be in h; the south magnetic pole in g; we have to ascertain where an arc from the latter falls at right angles into this meridian as in yy. Now yyh is obtained in the following trigonometrical manner. First $144° \; 50' - 90° = 54° \; 50'$, which is the same as the angle $yygh$; whence we obtain yyh trigonometrically as follows. As the radius $gyyh$ is to the side gh, so is the angle $hgyy$ to the side hyy. Or in numbers, thus; as the radius is to 22° 30′ so is 54° 50′ to $yyh = 18° \; 14'$.

Sine 22° 30′	9·58284
Sine 54° 50′	9·91247
	19·49531
Radius	10·00000
Sine 18° 14′	9·49531

20. We have next to ascertain the distance of this pole in the meridian from the place of observation, or *yyc*, which is done in the following manner by adding the sides to each other, viz. ;—*hyy*, and then 90°, or the side from *h* to the equator, and then the latitude, or distance from the equator to the place of observation; thus, 18° 14′+90°+51° 32′=159° 46′, the supplement of which is 20° 14′. This supplement is obtained in a better way, by subtracting the side *hyy* when found from the supplement of the latitude, thus; 38° 28′−18° 14′=20° 14′.

21. It is from this place that the ensuing calculation must be commenced, because it is distant from the pole 180°; and as in clause 9, so here also the minutes 35′ 20″, as found in clause 8, must be multiplied by a tenth of the distance 20° 14′, thus; $35' \, 20'' \times \frac{20^\circ \, 14'}{10} = 1^\circ \, 11'$; the reason of this is specified in clause 9.

22. But because nearer to the pole the twist of the spire is greater, and farther off it is less, the angle must be proportioned to the twist of the spire, or to its distance from the pole. Hence the reader is referred to the table in clause 12, where for the latitude of London we find the ratio 60 to 67, as we have said. Therefore 60 : 67 : : 1° 11′ : 1° 19′.

In order to obtain the northern reduced angle, we must add 1° 19′ to the true angle, as follows; 144° 50′+1° 19′ =146° 9′. The reason of this may be seen in clause 12. The southern reduced angle is therefore 146° 9′, and its supplement 33° 51′.

23. We have next to enquire for the side *gc* and the angle *gch*, as in the corresponding case of the north pole. In the first place let the side *gh* (fig. 94) be produced to *n*, where the arc *cn* falls at right angles into *n*. Then as the radius or angle *cnh* is to the sine *hc* (or its supplement to 180°, which is equal to 38° 28′=*ac*), so is the sine *dac* (=33° 51′, or the supplement of 146° 9′ to 180°, which is the angle at the south pole) to the sine *cn* (=20° 16′). By the logarithms of the sines thus;

Sine	38° 28′	9·79383
Sine	33° 51′	9·74587
		19·53970
Radius		10·00000
Sine	20° 16′	9·53970

We have thus the arc $cn = 20° 16'$.

24. In the next place we have to find *nh*; as follows. The cotangent *ch* ($= 38° 28'$) or as *ch*, the complement to the semicircle, is to the radius, so is the sine of the complement *chn* ($= 33° 51'$) to the tangent *nh* ($= 33° 25'$). By logarithms thus;

Cosine	33° 51′	9·91934
Radius		10·00000
		19·91934
Cotangent	38° 28′	10·09991
Tang.	33° 25′	9·81943

We thus obtain *nh*, if 33° 25′ be subtracted from 180°; but in our calculation we must use only 33° 25′.

25. We must proceed to ascertain the south side *gc* in the following manner. As the radius is to the sine of the complement *nc* ($= 20° 16'$), so is the sine of the complement *ng* ($= 8° 13'$) to the south side required ($= 21° 48'$), or to the supplement of 158° 12′, to 180°. But it is to be observed that *ng* is equal to 8° 13′, for this reason; viz., $nh = 146° 35'$, or its supplement is 33° 25′. If to this be added $hg = 25° 12'$, we have the whole side $= 171° 47'$; if this be subtracted from the semicircle so as to obtain the supplement, there remains 8° 13′, which is the sum to be used in the calculation. By logarithms thus;

Cosine	20° 16′	9·97224
Cosine	8° 13′	9·99552
		19·96776
Radius		10·00000
Cosine	21° 48′	9·96776

In order to obtain *gc*, we must take the supplement of 21° 48′ to the semicircle, which is 158° 12′.

26. We have next to ascertain the angle *gch*, which is done by sines in the following manner. As the sine *gc* (=21° 48′ for we must use the supplement of 158° 12′ to the semicircle) is to the sine *chg* (=33° 51′ for we must use the supplement of the angle *chg*=146° 9′), so is the sine *hg* (=25° 12′) to the angle *gch* (=39° 41′). Trigonometrically thus;

Sine 25° 12′	9·62918
Sine 33° 51′	9·74587
	19·37505
Sine 21° 48′	9·56980
Sine 39° 41′	9·80525

We have thus the angle *gch*=39° 41′, as also the side *gc*= 158° 12′.

27. We have thus the two sides and the two angles required; namely, the side *bc*=50° 54′; the angle *bca*=31° 37′. In like manner the south side *hc*=158° 12′; the angle *hcg*=39° 41′. Having obtained these sides and angles, we proceed proportionally thus. As the sum of the sides *bc*+*cg* (=50° 54′+158° 12′ =209° 6′) is to the sum of the angles, or *bca*+*gch* (=31° 37′+ 39° 41′=71° 18′), so is the north side *bc* (=50° 54′) to the angle *bcx* (=17° 14′). Or more clearly thus;

50° 54′		31° 37′
158° 12′		39° 41′
209° 6′	:	71° 18′ :: 50° 54′ : 17° 14.

28. Let the angle *bcx* (=17° 14′) be subtracted from the angle *bca*)=31° 37′), and there remains the angle *xca*=14° 23′, which is the same with the declination of the needle at London in the year 1722.

According to the observations of Mr Graham, instituted at

London, on March 8, 1722, the declination was 14° 22′; according to our present calculation it was 14° 23′, a difference of only one minute.[1]

In consequence of the anomalies which occur in the motion of the magnetic element, its tendency from one pole to another, and its spiral pressure and flow, we cannot use a shorter and more easy calculation; and although the process may appear laborious, yet by practice it becomes familiar. In the following examples therefore our explanations will be more brief and succinct, which will make the calculation appear not quite so prolix and circuitous.

II.

Calculation of the Magnetic Declination for the year 1700, *at London.*

Its latitude is 51° 32′ north, of which the complement is 38° 28′.

1) Between 1720 and 1700 there are 20 years intervening, whence 20 × 56′ = 18° 40′.

2) 112° 0′ + 18° 40′ = 130° 40′.

3) 130° 40′ − 90° = 40° 40′.

Sin. 22° 30′ 9·58284.
Sin. 40° 40′ 9·81402.

Sin. 14° 26 9·39686 for *pa*;

4) For the south angle, multiply as above 20 years by 20′, or 20 × 20′ = 6° 40′.

5) 145° 30′ + 6° 40′ = 152° 10′.

6) 152° 10′ − 90° = 62° 10′.

Sin. 22° 30′ 9·58284.
Sin. 62° 10′ 9·94660.

Sin. 19° 47′ 9·52944 for *oh*.

7) 38° 28′ + 14° 26′ = 52° 54′, or *pc*.

8) 52° 54′ × 6″ = 5′ 18″.

9) 22′ 30″ + 5′ 18″ = 27′ 48″.

10) 180° + 14° 26′ + 19° 47′ = 214° 13′, or *po*.

11) As the square of 180° = 32400 is to the square of 214° 13′ = 45800, so is 27′ 48″ to 40′.

12) 40′ × 52° 54′ = 3° 32′, by decimal calculation; or 40′ by 52° 54′.

13) 22° 30′ + 3° 32′ = 26° 2′, which is the same as the side or distance of the two poles to be used in the calculation; or *ba* and *hg*.

14) 60 : 67 :: 3° 32′ : 3° 57′; 130° 40′ − 3° 57′ = 126° 43′, which is therefore the angle *cab*, to

[1] *Philosophical Transactions*, vol. xxxiii. p. 102. Cited above at p. 11.—*Trs.*

be used in the calculation: its supplement is 53° 17′.

15) For *cd*;

Sine 38° 28′ 9·79383.

Sine 53° 17′ 9·90395.

Sine 29° 54′ 9·69778.

16) For *ad*;

Cosine 53° 17′ 9·77659

Radius 10·00000.

19·77659

Cotangent 10·09991 – 38° 28′.

Tangent 9·67668 – 25° 24′.

17) For *bc*; *bd* = *ba* + *ad*, or 25° 24′ + 26° 2′ = 51° 26′.

Cosine 29° 54′ 9·93796.

Cosine 51. 26′ 9·79478.

Cosine 57° 17′ 9·73274.

18) For the angle *bca* there will be the proportion 57° 17′ : 53° 17′ :: 26° 2′ : 24° 43′, or

Sine 26° 2′ 9·64236.

Sine 53° 17′ 9·90396.

19·54632.

Sine 57° 17′ 9·92497.

Sine 24° 43′ 9·62135, for *bca*. Thus we have the side *bc* = 57° 17′, and the angle *bca* = 24° 43′. Now for the south side and angle.

19) 38° 28′ – 19° 47′ = 18° 41′, for the supplement of the side *oc*.

20) By decimal calculation 40′ × 18° 41′ = 1° 15′.

21) For its increase; 60 : 67 :: 1° 15′ : 1° 24′.

22) 1° 24′ must be added to the south angle, or 152° 10′ + 1° 24′ = 153° 34, which is the south reduced angle: its supplement is 26° 26′.

23) For *nc*;

Sine 38° 28′ 9·79383.

Sine 26° 26′ 9·64851.

Sine 16° 5′ 9·44234. or *nc*;

24) For *nh*;

Cosine 26° 26′ 9·95204.

Radius 10·00000.

19·95204.

Cotangent 38° 28′ 10·09991.

Tangent 35° 26′ 9·85213.

25) For the side *gc* first subtract 35° 26′ – 26° 2′ = 9° 24′.

Cosine 16° 5′ 9·98266.

Cosine 9° 24′ 9·99413.

Cosine 18° 34′ 9·97679.

Its supplement gives the side *cg* = 161° 26′.

26) For the angle *gch* we shall have the proportion, as 18° 34′ to 26° 26′, or supp. of angle 153° 24′, so 26° 2′, or the reduced

distance, to 37° 58′, the angle required.

Sine 26° 2′ 9·64236.
Sine 26° 26′ 9·64851.

19·29087.
Sine 18° 34′ 9·50298.

Sine 37° 58′ 9·78889.

Thus we have the side *gc* = 161° 26′; and the angle *gch* = 37° 58′.

	Sides.	Angles
27)	57° 17′	24° 43′
	161° 26′	37° 58′
	218° 43′ :	62° 41′

:: 57° 17′ : 16° 29′.

28) If 16° 29′ be subtracted from the angle 24° 43′, there remains declination west 8° 14′.

According to observations made at London in the year 1700, the declination was 8° 0′, making, therefore, a difference of 0° 14′.

III.

Calculation of the Magnetic Declination for the year 1692, *at London.*

Its latitude is 51° 32′ north; its compl. 38° 28′.

1) Between 1720 and 1692 intervene 28 years; hence 28 × 56′ = 26° 8′.

2) 112° 0′ + 26° 8′ = 130° 8′, the true north angle.

3) 138° 8′ − 90° = 48° 8′, for *pa*.

Sine 22° 30′ 9·58284.
Sine 48° 8′ 9·87198.

Sine 16° 33′ 9·45482.

4) For the south angle, 28 × 20′ = 9° 20′.

5) 145° 30′ + 9° 20′ = 154° 50′, the true south angle.

6) For *oh*;

154° 50′ − 90° = 64° 50′, then

Sine 22° 30′ 9·58284.
Sine 64° 50′ 9·95668.

Sine 20° 16′ 9·53952.

7) For *pc* we have 38° 28′ + 16° 33′ = 55° 1′.

8) 55° 1′ × 6″ = 5′ 30″.

9) 22′ 30″ + 5′ 30″ = 28′ 0″.

10) For *po*,

180° + 16°33′ + 20°16′ = 216°49′.

11) The square of 180° = 32400, is to the square of 216° 49′ = 47000, as 28′ to 40′ 37″.

12) By decimal calculation; 40′ 37″ × 55° 1′ = 3° 43′.

13) 22° 30′ + 3° 43′ = 26° 13′, the reduced distance.

14) For the increase of the reduced angle; 60 : 67 :: 3° 43′ : 4° 9′.

Subtract this from the true angle, or 138° 8′ – 4° 9′ = 133° 59′. Thus the reduced angle is 133° 59′, the supplement of which is 46° 1′.

15) For *od*;

Sine 38° 28′ 9·79383.
Sine 46° 1′ 9·85705.

Sine 26° 35′ 9·65088.

16) For *ad*;

Cosine 46° 1′, and
Radius 19·84164
Cotangent 38° 28′ 10·09991

Tangent 28° 53′ 9·74173

17) For *bc*; *bd* = *ba* + *ad*, or 28° 53′ + 26° 13′ = 55° 6′.

Cosine 26° 35′ 9·95147.
Cosine 55° 6′ 9·75750.

Cosine 59° 14′ 9·70897.

18) For angle *bca* we shall have the proportion 59° 14′ : 46° 1′ :: 26° 13′ : 21° 43′, or

Sine 26° 13′ 9·64519.
Sine 46° 1′ 9·85705.

19·50224.
Sine 59° 14′ 9·93412.

Sine 21° 43′ 9·56812.

Thus we have the side *bc* = 59° 14′, and the angle *bca* = 21° 43′. Let us now find the side and angle at the south pole.

19) 38° 28′ – 20° 16 = 18° 12′, for the supplement of the side *oc*.

20) By decimal calculation, 40′ 37″ × 18° 12′ = 1° 13′.

21) The increase for that latitude; 60 : 67 :: 1° 13′ : 1° 21′.

22) Add 1° 21′ to the true south angle, that is to say, 154° 50′ + 1° 21′ = 156° 11′, and 156° 11′ is the south reduced angle and 23° 49′ its supplement.

23) For *nc*;

Sine 38° 28′ 9·79383.
Sine 23° 49′ 9·60617.

Sine 14° 33′ 9·40000.

24) For *nh*;

Cosine 23° 49′, and
Rad. 19·96134.
Cotangent 38° 28′ 10·09991.

Tang. 36° 1′ 9·86143.

25) For the side *gc*; 36° 1′ – 26° 13′ = 9° 48′.

Cosine 14° 33′ 9·98584.
Cosine 9° 48′ 9·99361.

Cosine 17° 29′ 9·97945.

Its supplement gives the side *cg* = 162° 31′,

26) For the angle *gch*, we

shall have the proportion; as 17° 29′ to 23° 49′, or to the supplement of the south reduced angle, so 26° 13′, or the reduced distance, to 36° 25′, or the angle required. By logarithms:

Sine 26° 13′ 9·64519.
Sine 23° 49′ 9·60617.

19·25136.
Sine 17° 29′ 9·47774.

Sine 36° 25′ 9·77362.

Thus we have the side $gc=$ 162° 31′, and the angle $gch=$ 36° 25′.

	Sides.	Angles.
27)	59° 14′	21° 43′.
	162° 31′	36° 25′.
	221° 45′ :	58° 8′

:: 59° 14′ : 15° 28′.

28) Subtract 15° 28′ from the angle 21° 43′, and there remains declination west 6° 15′.

According to observations it was 6° 0′, giving a difference of 0° 15′.

IV.

Calculation of the Magnetic Declination for the year 1735, *at London.*

Its latitude is 51° 32′ north; its complement 38° 28′.

1) Between 1720 and 1735 intervene 15 years, hence $15\times 56' = 14°$.

2) $112°\ 0' - 14°\ 0' = 98°\ 0'$.

3) For pa;
$98°\ 0' - 90° = 8°\ 0'$.
Sine 22° 30′ 9·58284.
Sine 8° 0′ 9·14355.

Sine 3° 3′ 8·72639.

4) For the true south angle, multiply, as above, 15 years by 20′, or $15\times 20' = 5°\ 0'$; therefore,

5) $145°\ 30' - 5°\ 0' = 140°\ 30'$, which is the true south angle.

6) For oh;
$140°\ 30' - 90° = 50°\ 30'$.
Sine 22° 30′ 9·58284.
Sine 50° 30′ 9·88740.

Sine 17° 10′ 9·47024.

7) For pc; $38°\ 28' + 3°\ 3' = 41°\ 31'$.

8) $41°\ 31' \times 6'' = 4'\ 9''$.

9) $22'\ 30'' + 4'\ 9'' = 26'\ 39''$.

10) For po;
$180° + 3°\ 3' + 17°\ 10' = 200°\ 13'$.

11) The square of $180° = 32400$: the square of $200°\ 13' = 40050$ :: 26′ 39″ : 33′.

12) By decimal calculation, $33' \times 41°\ 31' = 2°\ 17'$.

13) $22°\ 30' + 2°\ 17' = 24°\ 47'$,

which is the reduced distance.

14) For the increase of the reduced angle; 60 : 67 :: 2° 17′ : 2° 33′.
98° 0′ − 2° 33′ = 95° 27′, and 95° 27′ is the north reduced angle of which the supplement is 84° 33′.

15) For *cd*;

Sine	38° 28′	9·79383.
Sine	84° 33′	9·99803.
Sine	38° 15′	9·79186.

16) For *ad*;

Cosine with Radius	84° 33′	18·97762.
Cotangent	38° 28′	10·09991.
Tangent	4° 19′	8·87771.

17) For *bc*; *bd* = *ba* + *ad* = 24° 47′ + 4° 19′ = 29° 6′.

Cosine	38° 15′	9·89504.
Cosine	29° 6′	9·94139.
Cosine	46° 40′	9·83643.

18) For the angle *bca* there will be the proportion, 46° 40′ : 84° 33′ : : 24° 47′ : 35° 0′; or

Sine	24° 47′	9·62241.
Sine	84° 33′	9·99803.
		19·62044.
Sine	46° 40′	9·86175.
Sine	35° 0′	9·75869.

Thus we have the side *bc* = 46° 40′, and the angle *bca* = 35° 0′.

We have now to find the side and angle at the south pole.

19) 38° 28′ − 17° 10′ = 21° 18, for the supplement of the side *oc*.

20) By decimal calculation 33′ × 21° 18′ = 1° 9′.

21) For the increase at that latitude 60 : 67 : : 1° 9′ : 1° 17′.

22) Add 1° 17′ to the true south angle, that is to say, 140° 30′ + 1° 17′ = 141° 47′. And thus 141° 47′ is the true south redeuced angle; its supplement is 38° 13′.

23) For *nc*;

Sine	38° 28′	9·79383.
Sine	38° 13′	9·79143.
Sine	22° 38′	9·58526.

24) For *nh*;

Cosine and Radius	38° 13′	19·89524.
Cotangent	38° 28′	10·09991.
Tang.	31° 58′	9·79533.

25) For the side *gc*; 31° 58′ − 24° 47′ = 7° 11′.

Cosine	22° 38′	9·96519.
Cosine	7° 11′	9·99657.
Cosine	23° 42′	9·96176.

Its supplement gives the side *cg* = 156° 18′.

26) For the angle *gch* there will be the proportion 23° 42′ : 38° 13′ : : 24° 47′ : 40° 10′. By the logarithms of the sines :

Sine 24° 47′ 9·62241.
Sine 38° 13′ 9·79143.

19·41384.
Sine 23° 42′ 9·60417.

Sine 40° 10′ 9·80967.

Thus we have the side gc = 156° 18′, and the angle gch = 40° 10′.

	Sides.	Angles
27)	46° 40′	35° 0′
	156° 18′	40° 10′
	203° 8′ :	75° 10′

: : 46° 40′ : 17° 14′.

28) If 17° 14′ be subtracted from 35° 0′, there remains the declination west 17° 46′.

V.

Calculation of the Magnetic Declination for the year 1610, *at Paris.*

The latitude of the pole is 48° 51′. Its complement 41° 9′.

Longitude east from London 2° 25′.

1) Between 1610 and 1720 intervene 110 years: hence 110° × 56′ = 102° 40′.

2) Add these degrees together with the east longitude 2° 25′, to the north angle; 112° + 102° 40′ + 2° 25′ = 217° 5′; which subtracted from 360° leaves 142° 55′ to the east; and 142° 55′ is the true north angle.

3) For *pa*;
142° 55′ − 90 = 52° 55′.
Sine 22° 30′ 9·58284.
Sine 52° 55′ 9·90187.

Sine 17° 46′ 9·48471.

4) For the south angle, 110° × 20′ = 36° 40′.

5) Add these angles, together with the east longitude; namely. 145° 30′ + 36° 40′ + 2° 5′ = 184° 35′; which subtracted from 360°, leaves 175° 25′, the true south angle towards the east.

6) For *oh*;
175° 25′ − 90 = 85° 25′.
Sine 22° 30′ 9·58284.
Sine 85° 25′ 9·99860.

Sine 22° 25′ 9·58144.

7) For *pc*;
41° 9′ + 17° 46′ = 58° 55′.

8) 58° 55′ × 6″ = 5′ 54″.

9) Hence 22′ 30″ + 5′ 54″ = 28′ 24″.

10) For *po*;
180° + 17° 46′ + 22° 25′ = 220° 11′.

11) The square of 180 = 32400: the square of 220

= 48400, : : 28′ 24″ : 42′ 26″.

12) By decimal calculation; 42′ 26″ × 58° 55″ = 4° 10′.

13) 22° 30′ + 4° 10′ = 26° 40′, and 26° 40′ is the apparent side given by the calculation.

14) For the increase at this latitude may be considered as nil; for the ratio would be as 60 to 59½ : but add 4° 10′ to the true north angle 142° 55′; that is to say, 142° 55′ + 4° 10° = 147° 5′ toward the east; its supplement is 32° 55′.

15) For *cd*;

Sine	41° 9′	9·81824.
Sine	32° 55′	9·73523.
Sine	20° 57′	9·55347.

16) For *ad*;

Cosine	32° 55′ and	
Radius		19·92400.
Cotangent	41° 9′	10·05854.
Tang.	36° 16′	9·86546.

17) For *bc*; *bd* + *ba* = *ad*, or 26° 40′ + 36° 16′ = 62° 56′.

Cosine	20° 57′	9·97029.
Cosine	62° 56′	9·65803.
Cosine	64° 51′	9·62832.

18) For the angle *bca* there will be the proportion 64° 51′ : 32° 55′ : : 26° 40′ : 15° 38′

Sine	26° 40′	9·65205.
Sine	32° 55′	9·73523.
		19·38728.
Sine	64° 51′	9·95674.
Sine	15° 38′	9·43054.

Thus we have the side *bc* = 64° 51′, and the angle *bca* = 15° 38′.

We must now find the side and angle at the south pole.

19) For the supplement of the side *oc*; 41° 9′ − 22° 25′ = 18° 44′.

20) By decimal calculation 42′ 26″ × 18° 44′ = 1° 20′.

21) There is no need here of any increase of the angle.

22) Subtract 1° 20′ from the true south angle; that is, 175° 25′ − 1° 20° = 174° 5′; and 174° 5′ is the apparent reduced angle toward the east: its supplement is 5° 55′.

23) For *nc*;

Sine	41° 9′	9·81824.
Sine	5° 55′	9·01318.
Sine	3° 53′	8·83142.

24) For *nh*;

Cosine	5° 55′, and	
Radius		19·99768.
Cotangent	41° 9′	10·05854.
Tangent	41° 0′	9·93914.

25) For the side *gc*; 41° 0′ − 26° 40′ = 14° 20′.

Cosine 3° 53′ 9·99900.
Cosine 14° 20′ 9·98626.

Cosine 14° 51′ 9·98526.

Its supplement gives the side *cg* = 165° 9′.

26) For the angle *gch* there will be this proportion; 14° 51′ : 5° 55′ :: 26° 40′ : 10° 24′, or as the side sought, 14° 51′, to the supplement of the apparent reduced angle; so is 26° 40′, or the reduced distance to the angle in question. By sines:

Sine 26° 40′ 9·65205.
Sine 5° 55′ 9·01318.

18·66523.
Sine 14° 51′ 9·40873.

Sine 10° 24′ 9·25650.

	Sides.	Angles.
27)	64° 51′	15° 38′
	165° 9′	10° 24′
	230° 0′	26° 2′

:: 64° 51′ : 7° 20′.

28) If 7° 20′ be subtracted from 15° 38′, there remains the declination east 8° 18′.

According to observations made in that year, the declination was 8° 0′ toward the east; leaving a difference of 0° 18′.

VI.

Calculation of the Magnetic Declination for the year 1620, *at Paris.*

North latitude 48° 51: its complement 41° 9′.

Longitude east from London 2° 25′.

1) Between 1620 and 1720 intervene 100 years: hence 100 × 56′ = 93° 20′.

2) Add these degrees, 93° 20′, together with the longitude or distance of the meridians, to 112° 0′; or thus, 112° 0′ + 2° 25′ + 93° 20′ = 207° 45′; which subtracted from 360° leaves 152° 15′, the true north angle toward the east.

3) For *pa*;
152° 15′ − 90° = 62° 15′.

Sine 22° 30′ 9·58284.
Sine 62° 15′ 9·94693.

Sine 19° 47′ 9·52977.

4) For the south pole multiply as above; or 100 × 20′ = 33° 20′.

5) Add these degrees, together with the distance of the

longitude, to the south angle 145° 30′; that is, 145° 30′ + 33° 20′ + 2° 25 = 181° 15′, which subtracted from 360° leaves 178° 45′, the true south angle toward the east.

6) For *oh*;
178° 45′ − 90° = 88° 45′.
Sine 22° 30′ 9·58284.
Sine 88° 45′ 9·99989.

Sine 22° 30′ 9·58273.

7) For *pc*;
41° 9′ + 19° 47′ = 60° 56′.

8) 60° 56′ × 6″ = 6′ 6″.

9) Hence 22′ 30″ + 6′ 6″ = 28′ 36″.

10) For *po*;
180° 0′ + 19° 47′ + 22° 30′ = 222° 17′.

11) The square of 180° = 32400 is to the square of 222° 17′ = 49300, as 28′ 36″ to 43′ 18″.

12) By decimal calculation 43′ 18″ × 60° 56′ = 4° 23′.

13) 22° 30′ + 4° 23′ = 26° 53′; and thus 26° 53′ is the apparent reduced distance.

14) There is no need here of any increase: add 4° 23′ to the true north angle thus; 152° 15′ + 4° 23′ = 156° 38′; and 156° 38′ is the apparent north reduced angle. Its supplement is 23° 22′.

15) For *cd*;
Sine 41° 9′ 9·81824.
Sine 23° 22′ 9·59690.

Sine 15° 5′ 9·41514.

16) For *ad*
Cosine 23° 22′, and
Radius 19·96311.
Cotangent 41° 9′ 10·05854.

Tangent 38° 45′ 9·90457.

17) For *bc*; *bd* = *ba* + *ad*, or 38° 45′ + 26° 53′ = 65° 38′, hence
Cosine 15° 5′ 9·98477.
Cosine 65° 38′ 9·61550.

Csoine 66° 32′ 9·60027.

18) For the angle *bca* there will be this proportion; 66° 32′, the side found, is to 32° 17′, the supplement of the apparent angle, as 26° 53′, the apparent side, to the angle required. By sines:
Sine 26° 53′ 9·65530.
Sine 23° 17′ 9·59690.

19·25220.
Sine 66° 32′ 9·96250.

Sine 11° 14′ 9·28970.

Thus we have the side *bc* = 66° 32′, and the angle *bca* = 11° 14′.

We must now find the side and angle at the south pole.

19) For the supplement of the

side *oc*; 41° 9′ − 22° 30′ = 18° 39′.

20) By decimal calculation 43′ 18″ × 18° 39′ = 1° 20′.

21) Here there is no need of any increase.

22) Subtract 1° 20′ from the true south angle, thus, 178° 45′ − 1° 20′ = 177° 25′; and there is therefore 177° 25′ the apparent south reduced angle: its supplement is 2° 35′.

23) For *nc*;

Sine	41° 9′	9·81824.
Sine	2° 35′	8·65391.
Sine	1° 42′	8·47215.

24) For *nh*;

Cosine	2° 35′ and	
Radius		19·99950.
Cotangent	41° 9′	10·05854.
Tangent	41° 7′	9·94096.

25) For the side *gc*, first subtract; that is, 41° 7′—26° 53′ = 14° 14′.

Cosine	1° 42′	9·99981.
Cosine	14° 14′	9·98646.
Cosine	14° 21′	9·98627.

Its supplement gives the side required, that is, 180°—14° 21′ = 165° 39′.

26) For the angle *gch* there will be this proportion; as 14° 21′, or the side just found, to 2° 35′, or the supplement of the apparent reduced angle, which is 177° 25′; so is the apparent reduced distance, 26° 53′, to the angle required. By logarithms thus:

Sine	26° 53′	9·65530.
Sine	2° 35′	8·65391.
		18·30921.
Sine	14° 21′	9·39418.
Sine	4° 37′	8·90503.

Thus we have the side *gc* = 165° 39′ and the angle *gch* = 4° 37′.

	Sides.	Angles.
27)	66° 32′	11° 14′
	165° 39′	4° 37′
	232° 11′	= 15° 51′

: : 66° 32′ : 4° 33′

28) If 4° 33′ be subtracted from 11° 14′, there remains the declination east 6° 41′.

VII.

Calculation of the Magnetic Declination for the year 1630, *at Paris.*

North latitude 48° 51′, complement 41° 9′.

East longitude 2° 25′.

1) Between 1630 and 1720 intervene 90 years.

Hence 90 × 56′ = 84°.

2) Add these degrees together with the east longitude, to the angle 112°; that is, 112°+84° +2° 25′=198° 25′; which subtracted from 360° leaves the true north angle, 161° 35′ toward the east.

3) For *pa*;
161° 35′ − 90° = 71° 35′.
Sine 22° 30′ 9·58284.
Sine 71° 35′ 9·97716.

Sine 21° 17′ 9·56000.

4) For the south pole, multiply as above, thus
90 × 20′ = 30°.

5) Add these degrees together with the east longitude, to the angle 145° 30′; thus, 145° 30′ + 30° + 2° 25′ = 177° 55′. And the angle 177° 55′ is the true south angle toward the west.

6) For *oh*;
177° 55′ − 90° = 87° 55′.
Sine 22° 30′ 9·58284.
Sine 87° 55′ 9·99971.

Sine 22° 29′ 9·58255.

7) For *pc*;
41° 9′ + 21° 17′ = 62° 26′.

8) 62° 26′ × 6″ = 6′ 15″.

9) Hence 22′ 30″ + 6′ 15″ = 28′ 45″.

10) For *po*;
180° + 21° 17′ + 22° 29′ = 223° 46′.

11) The square of 180° = 32400, is to the square of 223° 46′ = 49600, as 28′ 45″ to 44′ 23.″

12) By decimal calculation 44′ 23″ × 62° 26′ = 4° 36′.

13) 22° 30′ + 4° 36′ = 27° 6′, and 27° 6′ is the apparent reduced distance.

14) For this latitude there is no need of any increase. But if 4° 36′ be added to the true north angle 161° 35′, we have the apparent north reduced angle 166° 11′, toward the east. The supplement of this is 13° 49′.

15) For *cd*;
Sine 41° 9′ 9·81824.
Sine 13° 49′ 9·37806.

Sine 9° 3′ 9·19630.

16) For *ad*;
Cosine 13° 49′ 19·98721.
Cotangent 41° 9′ 10·05854.

Tangent 40° 19′ 9·92867.

17) For *bc*; *bd* = *ba* + *ad*, or 27° 6′ + 40° 19′ = 67° 25′.
Cosine 9° 3′ 9·99459.
Cosine 67° 25′ 9·58436.

Cosine 69° 14′ 9·57895.

18) For the angle *bca* is this proportion; as 67° 25′, or the side found, is to 13° 49′, the supplement of the apparent angle; so is 27° 6′, or the ap-

parent angle, to the angle required :

Sine 27° 6′ 9·65853.
Sine 13° 49′ 9·37806.

19·03659.
Sine 69° 14′ 9·97082.

Sine 6° 41′ 9·06557.

Thus we have the side *bc* = 69° 14′, and the angle *bca* = 6° 41′.

We must now find the side and angle at the south pole.

19) For the supplement of the side *oc*; 41° 9′ − 22° 29′ = 18° 40′.

20) By decimal calculation 44′ 23″ × 18° 40′ = 1° 20′.

21) There is no need here of any increase or decrease.

22) Add 1° 20′ to the true south angle ; thus, 177° 55′ + 1° 20′ = 179° 15′ and thus 179° 15′ is the apparent reduced angle ; of which the supplement is 0° 45′.

23) For *nc* ;

Sine 41° 9′ 9·81824.
Sine 0° 45′ 8·11692.

Sine 0° 29′ 7·93516.

24) For *nh* ;

Sine Cosine with
Radius 0° 29′ 19·99998.
Cotangent 41° 9′ 10·05854.

Tangent 41° 9′ 9·94164.

25) For the side *gc*, first subtract thus ; 41° 9′ − 27° 6′ = 14° 3′.

Cosine 0° 29′ 9·99998.
Cosine 14° 3′ 9·98681.

Cosine 14° 3′ 9·98679.

Its supplement gives the side in question, or 165° 57′.

26) For the angle *gch* we have the proportion ; as 14° 3′, or the side found, to 0° 45′, or the supplement of the apparent south angle, so is 27° 6′, or the apparent side, to the angle. By sines :

Sine 27° 6′ 9·65853.
Sine 0° 45′ 8·11692.

17·77545.
Sine 14° 3′ 9·38519.

Sine 1° 24′ 8·39026.

Thus we have the side *gc* = 165° 57′, and the angle *gch* = 1° 24′.

27) Here subtract the angles, for the north magnetic pole is to the east, and the south magnetic pole to the west ; thus,

Sides.	Angles.
69° 14′	6° 41′
165° 57′	1° 24′

235° 11′ : 5° 17′ : : 69° 14′ : 1° 28′

28) If 1° 28′ be subtracted from 6° 41′, there remains the east declination 5° 13′.

VIII.

Calculation of the Magnetic Declination for the year 1640, *at Paris.*

Latitude of the place 48° 51′; its complement 41° 9′.

East longitude 2° 25′.

1) $1720-1640=80$; so that 80 years intervene, hence $80 \times 56'=74° 40'$.

2) Add these degrees, together with the east longitude, to the north angle 112° thus; $112°+74° 40'+2° 25'=189° 5'$, which subtracted from 360° leaves the true north angle 170° 55′ towards the east.

3) For *pa*;
$170° 55'-90°=80° 55'$; hence

Sine 22° 30′ 9·58284.
Sine 80° 55′ 9·99452.

Sine 22° 12′ 9·57736.

4) For the south pole multiply as above; $80 \times 20'=26° 40'$.

5) Add these degrees, together with the east longitude, to the south angle; $145° 30'+26° 40'+2° 25'=174° 35'$, which is the true south angle toward the west.

6) For *oh*; $174° 35'-90°=84° 35'$.

Sine 22° 30′ 9·58284.
Sine 84° 35′ 9·99805.

Sine 22° 23′ 9·58089.

7) For *pc*;
$41° 9'+22° 12'=63° 21'$.

8) $63° 21' \times 6''=6' 20''$.

9) Hence $22' 30''+6' 20''=28'' 50.''$

10) For *po*;
$180° 0'+22° 12'+22° 23'=224° 35'$.

11) The square of $180°=32400$: the square of 224° $35'=49900$ :: 28′ 50″ : 44′ 40″.

12) By decimal calculation, $44' 40'' \times 63° 21''=4° 41'$.

13) $22° 30'+4° 41'=27° 11'$; and thus 27° 11′ is the apparent reduced distance.

14) Here there is no need of any increase or decrease; but if 4° 41′ be simply added to the true north angle, 170° 55′; or, $4° 41'+170° 55'$, we have the apparent north reduced angle 175° 36′, toward the east; of which the supplement is 4° 24′.

15) For *cd*;

Sine 41° 9′ 9·81824.
Sine 4° 24′ 8·88490.

Sine 2° 58′ 8·70314.

16) For *ad*;

Cosine and

Radius 4° 24′ 19·99872.

Tang. 41° 9′ 10·05854.

Tangent 41° 4′ 9·94018.

17) For *bc* we have $bd = ba + ad$, or 41° 4′ + 27° 11′ = 68° 15′; or by logarithms:

Cosine 2° 58′ 9·99942.

Cosine 68° 15′ 9·56885.

Cosine 68° 17′ 9·56827.

18) For the angle *bca* we have the proportion; as 68° 17′, or the side found, to 4° 24′, the supplement of the apparent north angle, so is 27° 11′, the apparent reduced distance, to the angle required.

Sine 27° 11′ 9·65976.

Sine 4° 24′ 8·88490.

18·54466.

Sine 68° 17′ 9·96802.

Sine 2° 7′ 8·57664.

Thus we have the side bc = 68° 17′, and the angle bca = 2° 7′.

We must now find the side and angle at the south pole.

19) For the supplement of the side *oc*; 41° 9′ − 22° 23′ = 18° 46′.

20) By decimal calculation, 44′ 40″ × 18° 46′ = 1° 26′.

21) At this latitude there is no need of increase.

22) Add 1° 26′ to the true south angle: 174° 35′ + 1° 26′ = 176° 1′; and thus 176° 1′ is the apparent south reduced angle to the west; of which the supplement is 3° 59′.

23) For *nc*;

Sine 41° 9′ 9·81824.

Sine 3° 59′ 8·84177.

18·66001.

Radius 10·00000.

Sine 2° 37′ 8·66001.

24) For *nh*;

Cosine 3° 59′ and

Radius 19·99895.

Cotangent 41° 9′ 10·05854.

Tangent 41° 5′ 9·94041.

25) For the side *gc*; 41° 5′ — 27° 11′ = 13° 54′.

Cosine 2° 37′ 9·99954.

Cosine 13° 54′ 9·98709.

Cotangent 14° 9′ 9·98663.

Its supplement to 180° gives the side required gc = 165° 51′.

26) For the angle *gch* we have the proportion, as 14° 9′, or the side found, to 3° 59′, the supplement of the apparent south angle, so is 27° 11′, or the apparent reduced distance, to the angle required. By logarithms:

Sine 27° 11′ 9·65976.
Sine 3° 59′ 8·84177.

18·50153.
Sine 14° 9′ 9·38821.

Sine 7° 28′ 9·11332.

Thus we have the side *go* = 165° 51′, and the angle *gch* = 7° 28′.

27) Since one angle is to the east, the other to the west, they are not to be added, but subtracted, in order that in the operation the difference may be used.

Sides.	Angles.
68° 17′	2° 7′—difference.
165° 51′	7° 28′
234° 8′ :	5° 21′ : : 68° 17′ : 1° 29′

28) If 1° 29′ be added to 2° 7′, we have the declination east 3° 36′.

IX.

Calculation of the Magnetic Declination for the year 1650, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

East longitude 2° 25′.

1) 1720—1650 = 70, so that 70 years intervene; hence 70 × 56′ = 65° 20′.

2) Add these degrees together with the longitude 2° 25′, to the angle 112°, thus; 112° 0′ + 65° 20′ + 2° 25′ = 179° 45′; and 179° 45′ is thus the true north angle toward the west.

3) For *pa*;
First 179° 45′ − 90° = 89° 45′.
Sine 22° 30′ 9·58284.
Sine 89° 45′ 9·99999.

Sine 22° 30′ 9·58283.

4) For the south pole, multiply as above: 70 × 20′ = 23° 20′, the number of years which intervene.

5) Add these degrees together with the east longitude, that is, 145° 30′ + 2° 25′ + 23° 20′ = 171° 15′, and 171° 15′ is the true south angle toward the west.

6) For *oh*;
171° 15′ − 90° = 81° 15′.
Sine 22° 30′ 9·58284.
Sine 81° 15′ 9·99491.

Sine 22° 13′ 9·57775.

7) For *pc*;
41° 9′ + 22° 30′ = 63° 39′.

8) 63° 39′ × 6″ = 6′ 21″.

9) Hence, 22′ 30″ + 6′ 21″ = 28′ 51″.

10) For *po*;
180° + 22° 30′ + 22° 13′ = 224° 43′.

11) The square of $180 = 32410$: the square of $224° 43' = 50500 :: 28' 51'' : 45' 13''$.

12) By decimal calculation, $45' 13'' \times 63° 39' = 4° 47'$.

13) $22° 30' + 4° 47' = 27° 17'$ = the apparent reduced distance.

14) At this latitude there is no need of increase or decrease; but subtract 4° 47′ from the true north angle: $179° 45' - 4° 47' = 174° 58'$, and 174° 58′ is the apparent north reduced angle, lying toward the west, of which the supplement is 5° 2′.

15) For *cd*;

Sine	41° 9′	9·81824.
Sine	5° 2′	8·94317.
Sine	3° 18′	8·76141.

16) For *ad*;

Cosine	5° 2′, and	
Radius		19·99832.
Cotangent	41° 9′	10·05854.
Tangent	41° 2′	9·93978.

17) For *bc*, we have first $ba + ad = bd$, or $27° 17' + 41° 2' = 68° 19'$; then by logarithms:

Cosine	3° 18′	9·99928.
Cosine	68° 19′	9·56758.
Cosine	68° 22′	9·56686.

18) For the angle *bca* we have the proportion, as 68° 22′, or the side just found, to 5° 2′, or the supplement of the apparent north angle; so is 27° 17′, or the apparent reduced distance, to the angle required.

Sine	27° 17′	9·66123.
Sine	5° 2′	8·94317.
		18·60440.
Sine	68° 22′	9·96827.
Sine	2° 29′	8·63613.

Thus we have the side $bc = 68° 22'$; and the angle $bca = 2° 29'$.

We must now find the side and angle about the south pole.

19) For the supplement of the side *oc*, $41° 9' - 22° 13' = 18° 56'$.

20) By decimal calculation, $45' 13'' \times 18° 56' = 1° 26'$.

21) Here there is no need of any increase or decrease.

22) Add 1° 26′ to the true south angle thus; $171° 15' + 1° 26' = 172° 41'$; and thus 172° 41′ is the apparent south reduced angle toward the west; whose supplement is 7° 19′.

23) For *nc*;

Sine	41° 9′	9·81824.
Sine	7° 19′	9·10501.
Sine	4° 48′	8·92325.

24) For *nh*;

Cosine 7° 19′, with
Radius 19·99645.
Cotangent 41° 9′ 10·05854.

Tangent 40° 55′ 9·93791.

25) For the side gc subtract thus; 40° 55′ − 27° 17′ = 13° 38′.

Cosine 4° 48′ 9·99847.
Cosine 13° 38′ 9·98758.

Cosine 14° 27′ 9·98605.

Its supplement gives the side cg; 165° 33′.

26) For the angle gch we have the proportion, as 14° 27′, or the side now found, to 7° 19′, or the supplement of the apparent south angle, so is 27° 17′, or the apparent reduced distance, to the angle required. By sines:

Sine 27° 17′ 9·66123.
Sine 7° 19′ 9·10501.

18·76624.
Sine 14° 27′ 9·39713.

Sine 13° 32′ 9·36911.

Thus we have the side gc = 165° 33′; and the angle gch = 13° 32′.

	Sides.	Angles.
27)	68° 22′	2° 29′
	165° 33′	13° 32′
	233° 55′ :	16° 1′

:: 68° 22′ : 4° 40′.

28) If 2° 29′ be subtracted from 4° 40′, there remains the declination east 2° 11′.

X.

Calculation of the Magnetic Declination for the year 1665, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

East longitude from London 2° 25′.

1) 1720 − 1665 = 55: so that 55 years intervene; hence 55 × 56′ = 51° 20′.

2) Add these degrees, together with the distance of the east longitude, to the north angle thus; 112° + 51° 20′ + 2° 25′ = 165° 45′; which is the true north angle to the west.

3) For pa;
165° 45′ − 90° = 75° 45′.

Sine 22° 30′ 9·58284.
Sine 75° 45′ 9·98642.

Sine 21° 46′ 9·56926.

4) For the south pole, multiply as above thus:
55 × 20′ = 18° 20′.

5) Add these degrees, together with the longitude, to the south angle, 145° 30′+18° 20′ +2° 25′=166° 15′, which is the true south angle, to the west.

6) For *oh* ;
166° 15′−90°=76° 15′.
Sine 22° 30′ 9·58284.
Sine 76° 15′ 9·98737.

Sine 21° 49′ 9·57021.

7) For *pc*, 41° 9′+21° 46′= 62° 55′.

8) 62° 55′×6″=6′ 18″.

9) Hence 22′ 30″+6′ 18″=28′ 48″.

10) For *po* ;
180° + 21°46′ + 21°49′ = 223° 35′.

11) The square of 180°= 32400 : the square of 223° 35′= 49929 :: 28′ 48″ : 44′ 20″.

12) By decimal calculation, 44′ 20″×62° 55′=4° 39′.

13) 22° 30′+4° 39′=27° 9′, which is the apparent reduced distance.

14) Here there is no need of increase, but subtract thus; 165° 45′−4° 39′=161° 6′, which is the apparent north reduced angle, of which the supplement to the semicircle is 18° 54′, toward the west.

15) For *cd* ;
Sine 41° 9′ 9·81824.
Sine 18° 54′ 9·51043.

Sine 12° 18′ 9·32867.

16) For *ad* ;
Cosine 18° 54′ and
Rad. 19·97593.
Cotangent 41° 9′ 10·05854.

Tangent 39° 35′ 9·91739.

17) For *bc* add thus; *bd*=*ba* +*ad*, or 39° 35′+27° 9′=66° 44′; hence,
Cosine 12° 18′ 9·98991.
Cosine 66° 44′ 9·59661.

Cosine 67° 18′ 9·58652.

18) For the angle *bca* we have the proportion; as 67° 18′, or the side just found, to 18° 54′, or the supplement of the apparent north angle; so is 27° 9′, or the apparent side, to the required angle, *bca*.
Sine 27° 9′ 9·65927.
Sine 18° 54′ 9·51043.

19·16970.
Sine 67° 18′ 9·96498.

Sine 9° 13′ 9·20472.

Thus we have the side *bc*=67° 18′; and the angle *bca*=9° 13′.

We must now find the angle and side at the south pole.

19) For the supplement of the

side *oc*; 41° 9′ − 21° 49′ = 19° 20′.

20) By decimal calculation, 44′ 20″ × 19° 20′ = 1° 23′.

21) There is no need here of any increase.

22) Add 1° 23′ to the south reduced angle thus; 166° 15′ + 1° 23′ = 167° 38′, which is the apparent south reduced angle lying toward the west; its supplement is 12° 22′.

23) For *nc*;

Sine 41° 9′ 9·81824.
Sine 12° 22′ 9·33075.

Sine 8° 6′ 9·14899.

24) For *nh*;

Cosine and
Radius 12° 22′ 19·98980.
Cotangent 41° 9′ 10·05854.

Tangent 40° 29′ 9·93126.

25) For the side *gc* first subtract thus; 40° 29′ − 27° 9′ = 13° 20′.

Cosine 8° 6′ 9·99564.
Cosine 13° 21′ 9·98810.

Cosine 15° 35′ 9·98374.

Its supplement gives the side required, or *cg* = 164° 25′.

26) For the angle *gch* we have the proportion, as 15° 35′, or the side now found, to 12° 22′, or the supplement of the apparent south angle, so is 27° 9′, or the apparent side, to the angle required.

Sine 27° 9′ 9·65927.
Sine 12° 22′ 9·33075.

18·99002.
Sine 15° 35′ 9·42962.

Sine 21° 20′ 9·56040.

Thus we have the side *gc* = 164° 25′; and the angle *gch* = 21° 20′.

	Sides.	Angles.
27)	67° 18′	9° 13′
	164° 25′	21° 20′
	231° 43′ :	30° 33′

:: 67° 18′: 8° 53′.

28) If 8° 53′ be subtracted from 9° 13′, there remains the declination west 0° 20′. According to this calculation, there would be in the year 1664 no declination at Paris, but not so in the year 1666: so that between 1664 and 1670, there would be a difference of 1° 30′; but not between 1666 and 1670 as appears from observations; according to which the progression must have been 1° 30′ within three or four years, and must have made a considerable leap every year, namely, 38′, which appears too much. If there had been no declination in the year

1664, there would then be an annual progression of about 20′ or 23′; as seems also a possible conclusion from the experiments which precede, and from those which follow.

XI.

Calculation of the Magnetic Declination for the year 1670, *at Paris.*

North latitude 48° 51′; complement 41° 9′.

East longitude from London, 2° 25′.

1) 1720 − 1670 = 50; that is, 50 years intervene: hence 50 × 56′ = 46° 4′.

2) Add these degrees, together with the east longitude, to the north angle at London; thus 112° + 2° 25′ + 46° 4′ = 160° 29′, toward the west.

3) For *pa*;

160° 29′ − 90° = 70° 29′.

Sine 22° 30′ 9·58284.

Sine 70° 29′ 9·97430.

Sine 21° 8′ 9·55714.

4) For the south pole multiply as above thus; 50 × 20′ = 16° 40′.

5) Add these degrees, together with the east longitude, to the south angle at London thus; 145° 30′ + 2° 25′ + 16° 40′ = 164° 35′, toward the west.

6) For *oh*;

164° 35′ − 90° = 74° 35′.

Sine 22° 30′ 9·58284.

Sine 74° 35′ 9·98408.

Sine 21° 39′ 9·56692.

7) For *pc*;

41° 9′ + 21° 8′ = 62° 17′.

8) 62° 17′ × 6″ = 6′ 14″.

9) Hence 22′ 30″ + 6′ 14″ = 28′ 44″.

10) For *po*;

180° + 21° 8′ + 21° 39′ = 222° 47′.

11) The square of 180 = 32400 : the square of 222° 47′ = 49600 :: 28′ 44″ : 44′ 20″.

12) By decimal calculation, 44′ 20″ × 62° 17′ = 4° 35′.

13) 22° 30′ + 4° 35′ = 27° 5′; whence 27° 5′ is the apparent north reduced distance.

14) At this latitude there is no need of any increase or decrease, but subtract 4° 35′ from the true north angle; viz., 160° 29′ − 4° 35′ = 155° 54′, which is the apparent north reduced angle toward the west; of which the supplement is 24° 6′.

15) For *cd*;
Sine 41° 9′ 9·81824.
Sine 24° 6′ 9·61101.

Sine 15° 35′ 9·42925.

16) For *ad*;
Cosine 24° 6′, and
Radius 19·96039.
Cotangent 41° 9′ 10·05854.

Tangent 38° 35′ 9·90185.

17) For *bc* we have first *bd* $=ba+ad$, or 38° 35′ + 27° 5′ = 65° 40′.
Cosine 15° 35′ 9·98373.
Cosine 65° 40′ 9·61494.

Cosine 66° 37′ 9·59867.

18) For the angle *bca* we have the proportion; as 66° 37′, the side now found, to 24° 6′, the supplement of the apparent north angle; so is 27° 5′, the apparent side, to the angle required.
Sine 27° 5′ 9·65828.
Sine 24° 6′ 9·61101.

19·26929.
Sine 66° 37′ 9·96278.

Sine 11° 41′ 9·30651.

Thus we have the side bc = 66° 37′, and the angle bca = 11° 41′.

We must now find the side and angle at the south pole.

19) For the supplement of the side *oc*; 41° 9′ − 21° 39′ = 19° 30′.

20) By decimal calculation, 44′ 20″ × 19° 30′ = 1° 28′.

21) There is no need here of any increase.

22) But merely add 1° 28′ to the true south angle thus; 164° 35′ + 1° 28′ = 166° 3′, which is the apparent south reduced angle toward the west, of which the supplement is 13° 57′.

23) For *nc*;
Sine 41° 9′ 9·81824.
Sine 13° 57′ 9·38215.

Sine 9° 8′ 9·20039.

24) For *nh*;
Cosine with
Radius 13° 57′ 19·98699.
Cotangent 41° 9′ 10·05854.

Tangent 40° 18′ 9·92845.

25) For the side *gc*, first subtract thus; 40° 18′ − 27° 5′ = 13° 13′.
Cosine 9° 8′ 9·99445.
Cosine 13° 13′ 9·98834.

Cosine 16° 2′ 9·98279.

Its supplement gives the side *cg*, that is, 163° 58′.

26) For the angle *gch* we have the proportion; as 16° 2′, or the supplement of the side

found, to 13° 57′, the supplement of the apparent north angle ; so is 27° 5′, the apparent side of calculation, to the angle required.

Sine 27° 5′ 9·65828.
Sine 13° 57′ 9·38215.

19·04043.
Sine 16° 2′ 9·44121.

Sine 23° 25′ 9·59922.

Thus we have the side gc= 163° 58′, and the angle gch= 23° 25′.

	Sides.	Angles.
27)	66° 37′	11° 41′
	163° 58′	23° 25′
	230° 35′ :	35° 6′

:: 66° 37′ : 10° 6′.

28) If 10° 6′ be subtracted from the angle 11° 41′, there remains the declination west 1° 35′.

According to observations the declination west was 1° 30′, whence there is a difference of 0° 5′.

XII.

Calculation of the Magnetic Declination for the year 1680, *at Paris.*

North latitude 48° 51′ ; complement 41° 9′.

East longitude from London 2° 25′.

1) 1720 − 1680 = 40 ; whence 40 years intervene ; therefore 40 × 56′ = 37° 20′.

2) Add these degrees together with the longitude, to the north angle at London thus ; 112° + 2° 25′ + 37° 20′ = 151° 45′.

3) For *pa* ;
151° 45′ − 90° = 61° 45′.
Sine 22° 30′ 9·58284.
Sine 61° 45′ 9·94492.

Sine 19° 42′ 9·52776.

4) For the south pole multiply as above thus; 40 × 20′ = 13° 20′.

5) Add these degrees together with the longitude, to the south angle at London thus ; 145° 30′ + 2° 25′ + 13° 20′ = 161° 15′, which is the true south angle to the west.

6) For *oh* ;
161° 15′ − 90° = 71° 15′.
Sine 22° 30′ 9·58284.
Sine 71° 15′ 9·97631.

Sine 21° 15′ 9·55915.

7) For *pc* ;
41° 9′ + 19° 42′ = 60° 51′.

8) 60° 51′ × 6″ = 6′ 6″.

9) Hence $22' 30'' + 6' 6'' = 28' 36''$.

10) For *po*;
$180° + 19° 42' + 21° 15' = 220° 57'$.

11) The square of $180 = 32400$: the square of $220° 57' = 48641$ :: $28' 36''$: $42' 52''$.

12) By decimal calculation, $42' 52'' \times 60° 51' = 4° 21'$.

13) $22° 30' + 4° 21' = 26° 51'$, which is the apparent side of calculation.

14) There is no need of any increase; but subtract $4° 21'$ from the true north angle thus; $151° 45' - 4° 21' = 147° 24'$, which is the apparent north reduced angle to the west; whose supplement is $32° 36'$.

15) For *cd*;

Sine	41° 9′	9·81824.
Sine	32° 36′	9·73140.
Sine	20° 46′	9·54964.

16) For *ad*;

Cosine with Radius	32° 26′	19·92554.
Cotangent	41° 9′	10·05854.
Tangent	36° 22′	9·86700.

17) For *bc* add thus; $ba + ad = bd$, or $36° 22' + 26° 51' = 63° 13'$.

Cosine	20° 46′	9·97082.
Cosine	63° 13′	9·65380.
Cosine	65° 5′	9·62462.

18) For the angle *bca* we have the proportion; as 65° 5′, the side now found, to 32° 36′, the supplement of the apparent north angle; so is 26° 51′, the apparent side, to the angle required.

Sine	26° 51′	9·65480.
Sine	32° 36′	9·73140.
		19·38620.
Sine	65° 5′	9·95756.
Sine	15° 34′	9·42864.

Thus we have the side $bc = 65° 5'$, and the angle $bca = 15° 41'$.

We must now find the side and angle at the south pole.

19) For the supplement of the side *oc*; $41° 9' - 21° 15' = 19° 54'$.

20) By decimal calculation, $19° 54' \times 42' 52'' = 1° 25'$.

21, 22) Here there is no need of any increase; but add 1° 25′ to the true south angle thus; $161° 15' + 1° 25' = 162° 40'$, which is the apparent south reduced angle to the west; of which the supplement is 17° 20′.

23) For *nc*;

Sine	41° 9′	9·81824.
Sine	17° 20′	9·47411.
Sine	11° 18′	9·29235.

24) For *nh*;

Cosine with Radius	17° 20′	19·97981.
Cotangent	41° 9′	10·05854.
Tangent	39° 50′	9·92127.

25) For the side *gc*; 39° 50′ – 26° 51′ = 12° 59′.

Cosine	11° 18′	9·99149.
Cosine	12° 59′	9·98889.
Cosine	17° 6′	9·98038.

Its supplement to 180° gives the side *gc* = 162° 54.′

26) For the angle *gch* we have the proportion; as 17° 6′, or the supplement of the side now found, to 17° 20′, or the supplement of the apparent south angle, so is 26° 51′, or the apparent side, to the angle required.

Sine 26° 51′	9·65480.
Sine 17° 20′	9·47411.
	19·12891.
Sine 17° 6′	9·46840.
Sine 27° 14′	9·66051.

Thus we have the side *gc* = 162° 54′; and the angle *gch* = 27° 14′.

	Sides.	Angles.
27)	64° 10′	15° 34′
	162° 54′	27° 14′
	227° 4′ :	42° 48′

:: 64° 10′ : 12° 5′.

28) If 12° 5′ be subtracted from 15° 34′, there remains the declination west 3° 29′.

Experiments show, that in the year 1680 the declination west was 2° 40′; so that the difference would be 0° 49′; but they do not make the difference greater between the years 1670 and 1680, than 1° 10′; likewise also between the years 1680 and 1683 they make a difference of 1° 10′, which does not seem to be in agreement with the progression of the declination, because it is thus the same within 10 years, as within three years; so that my calculation seems to have taken a mean, and to have fixed the declination at 3° 39′.

In section 27, 64° 10′ should be 65° 5′. Resulting declination is 3° 34′.—*Trs.*

XIII.

Calculation of the Magnetic Declination for the year 1690, *at Paris.*

North latitude 48° 51′, complement 41° 9′.

East longitude 2° 25′.

1) 30 years intervene between 1690 and 1720; hence 30 × 56′ = 28°.

2) Add these degrees, together with the east longitude from London: $112° + 2°\ 25' + 28° = 142°\ 25'$, which is the true north angle.

3) For *pa*;

$142°\ 25' - 90° = 52°\ 25'$.

Sine $22°\ 30'$ 9·58284.

Sine $52°\ 25'$ 9·89898.

Sine $17°\ 39'$ 9·48172.

4) For the south pole, multiply as above, $30 \times 20' = 10°$.

5) Add these degrees, with the longitude, to the south angle thus; $145°\ 30' + 2°\ 25' + 10° = 157°\ 55'$, and this is the true south angle, to the west.

6) For *oh*;

$157°\ 55' - 90° = 67°\ 55'$.

Sine $22°\ 30'$ 9·58284.

Sine $67°\ 55'$ 9·96691.

Sine $20°\ 46'$ 9·54975.

7) For *pc*;

$41°\ 9' + 17°\ 39' = 58°\ 48'$.

8) $58°\ 48' \times 6'' = 5°\ 52'$.

9) Hence $22'\ 30'' + 5'\ 52'' = 28'\ 22''$.

10) For *po*;

$180° + 17°\ 39' + 20°\ 46' = 218°\ 25'$.

11) The square of $180° = 32400$: the square of $218°\ 25' = 47600 :: 28'\ 22'' : 41'\ 40''$.

12) By decimal calculation, $41'\ 40'' \times 58°\ 48' = 4°\ 5'$.

13) $22°\ 30' + 4°\ 5' = 26°\ 35'$, which is the apparent reduced distance.

14) Here there is no need of increase, but subtract $4°\ 5'$ from the true north angle thus; $142°\ 25' - 4°\ 5' = 138°\ 20'$, which is the apparent north reduced angle to the west; of which the supplement is $41°\ 40'$.

15) For *cd*;

Sine $41°\ 9'$ 9·81824.

Sine $41°\ 40'$ 9·82268.

Sine $25°\ 56'$ 9·64092.

16) For *ad*;

Cosine with Radius	$41°\ 40'$	19·87333.
Cotangent	$41°\ 9'$	10·05854.
Tangent	$33°\ 8'$	9·81479.

17) For *bc* first add; $ba + ad = bc$; or $33°\ 8' + 26°\ 35' = 59°\ 43'$.

Cosine $25°\ 56'$ 9·95390.

Cosine $59°\ 43'$ 9·70267.

Cosine $63°\ 2'$ 9·65657.

18) For the angle *bca* we have the proportion; as $63°\ 2'$, the side now found, to $41°\ 40'$, the supplement of the apparent north angle, so is $26°\ 35'$, the apparent side, to the angle required.

Sine 26° 35′ 9·65079.
Sine 41° 40′ 9·82268.

19·47347.
Sine 63° 2′ 9·95001.

Sine 19° 30′ 9·52346.

Thus we have the side *bc*=63° 2′, and the angle *bca*=19° 30′. We must now find the side and angle at the south pole.

19) For the supplement of the side *oc*; 41° 9′−20° 46′=20° 23′.

20) By decimal calculation, 20° 23′×41′ 40″=1° 23′.

21) At this latitude there is no need of increase.

22) Add therefore 1° 23′ to the true south angle; or 157° 35′+1° 23′=158° 58′, which is the apparent south reduced angle, lying to the west; of which the supplement is 21° 2′.

23) For *nc*;

Sine 41° 9′ 9·81824.
Sine 21° 2′ 9·55498.

Sine 13° 40′ 9·37322.

24) For *nh*;

Cosine and Radius	21° 2′	19·97005.
Cotangent	41° 9′	10·05854.
Tangent	39° 12′	9·91151.

25) For the side *gc* first subtract; or 39° 12′−26° 35′=12° 37′; hence

Cosine 13° 40′ 9·98752.
Cosine 12° 37′ 9·98938.

Cosine 18° 31′ 9·97690.

Its supplement to 180° gives the side required *cg*=161° 29′.

26) For the angle *gch* we have the proportion; as 18° 31′, or the side now found, to 21° 2′, the supplement of the apparent south angle; so is 26° 35′, or the apparent side, to the angle required.

Sine 26° 35′ 9·65079.
Sine 21° 2′ 9·55466.

19·20545.
Sine 18° 31′ 9·50185.

Sine 30° 21′ 9·70360.

Thus we have the side *gc*=161° 29′ and the angle *gch*=30° 21′.

	Sides.	Angles.
27)	63° 2′	19° 30′
	161° 29′	30° 21′
	224° 31′ :	49° 51′

:: 63° 2′ : 14° 0′.

28) Subtract 14° 0′ from the north angle, 19° 30′, and there remains the declination west 5° 30′, for the year 1690.

XIV.

Calculation of the Magnetic Declination for the year 1700, at Paris.

North latitude 48° 51′; complement 41° 9′.

Longitude east from London 2° 25′.

1) 1720 − 1700 = 20: thus 20 years intervene; hence 20 × 56′ = 18° 40′.

2) Add these degrees together with the east longitude thus; 112° + 2° 25′ + 18° 40′ = 133° 5′, which is the true north angle.

3) For *pa*;
133° 5′ − 90° = 43° 5′.
Sine 22° 30′ 9·58284.
Sine 43° 5′ 9·83446.

Sine 15° 9′ 9·41730.

4) For the south pole multiply as above; or 20 × 20′ = 6° 40′.

5) Add these degrees, together with the longitude, to the south angle at London; or 145° 30′ + 2° 25′ + 6° 40′ = 154° 35′, which is the true south angle.

6) For *oh*;
154° 35° − 90° = 64° 35′.
Sine 22° 30′ 9·58284.
Sine 64° 35′ 9·95579.

Sine 20° 13′ 9·53863.

7) For *pc*;
41° 9′ + 15° 9′ = 56° 18′.

8) 56° 18′ × 6″ = 5′ 38″.

9) Hence 22′ 30″ + 5′ 38″ = 28′ 8″.

10) For *po*;
180° + 15° 9′ + 20° 13′ = 215° 22′.

11) The square of 180 = 32400 : the square of 215° 22′ = 46400 :: 28′ 8″ : 40′ 6″.

12) By decimal calculation; 40′ 6″ × 56° 18′ = 3° 44.′

13) 22° 30′ + 3° 44′ = 26° 14′, which is the apparent reduced distance.

14) There is no need here of either increase or decrease; but merely subtract 3° 44′ from the true north angle; or 133° 5′ − 3° 44′ = 129° 21′, which is the apparent north reduced angle at the west; of which the supplement is 50° 39′.

15) For *cd*;
Sine 41° 9′ 9·81824.
Sine 50° 39′ 9·88834.

Sine 30° 35′ 9·70658.

16) For *ad*;

Cosine and Radius	50° 39′	19·80212.
Cotangent	41° 9′	10·05854.
Tangent	28° 59′	9·74358.

17) For *bc* add thus; *ba* + *ad*

$=bd$; or 28° 59′ + 26° 14′ = 55° 13′.

Cosine	30° 35′	9·93494.
Cosine	55° 13′	9·75623.
Cosine	60° 35′	9·69117.

18) For the angle *bca* we have the proportion; as 60° 35′, or the side found, to 50° 39′, or the supplement of the apparent angle, so is 26° 14′, or the apparent reduced distance to the angle required.

Sine	26° 14′	9·64545.
Sine	50° 39′	9·88834.
		19·53379.
Sine	60° 35′	9·94005.
Sine	23° 6′	9·59374.

And thus we have the side *bc* = 60° 35′, and the angle *bca* = 23° 6′.

We must now find the side and angle at the south pole.

19) For the supplement of the side *oc*; 41° 9′ − 20° 13′ = 20° 56′.

20) By decimal calculation, 20° 56′ × 40′ 6″ = 1° 24′.

21) There is no need here of any reduction.

22) But add 1° 24′ to the true south angle; or 154° 35′ + 1° 24′ = 155° 59′, which is the apparent south reduced angle lying toward the west; the supplement of which is 24° 1′.

23) For *nc*;

Sine	41° 9′	9·81824.
Sine	24° 1′	9·60959.
Sine	15° 32′	9·42783.

24) For *nh*;

Cosine with Radius	24° 1′	19·96067.
Cotangent	41° 9′	10·05854.
Tangent	38° 32′	9·90113.

25) For the side *gc* first subtract thus: 38° 32′ − 26° 14′ = 12° 18′.

Cosine	15° 33′	9·98380.
Cosine	12° 18′	9·98991.
Cosine	19° 43′	9·97371.

Its supplement gives the side *cg* = 160° 17′.

26) For the angle *gch* we have the proportion; as 19° 43′, the side now found, to 24° 1′, the supplement of the apparent south angle, so is 26° 14′, or the apparent reduced distance to the angle required.

Sine	26° 14′	9·64545.
Sine	24° 1′	9·60959.
		19·25504.
Sine	19° 43′	9·52810.
Sine	32° 13′	9·72694.

Thus we have the side *go* =

160° 17′; likewise the angle *gch* = 32° 13′.

	Sides.	Angles.
27)	60° 35′	23° 6′.
	160° 17′	32° 13′.
	220° 52′ :	55° 19′

:: 60° 35′ : 15° 6′.

28) If 15° 6′ be subtracted from 23° 6′, there remains the declination west 8° 0′. According to observations the declination west seems to have been 8° 12′; whence there is a difference of 0° 12′.

XV.

Calculation of the Magnetic Declination for the year 1710, *at Paris.*

North latitude 48° 51′; complement 41° 9′.

Longitude east from London 2° 25′.

1) 1720 − 1710 = 10; thus ten years intervene; hence 10 × 56′ = 9° 20′.

2) Add these degrees, together with the east longitude, to the north angle at London; thus 112° + 2° 25′ + 9° 20′ = 123° 45′, which is the true north angle.

3) For *pa*;
123° 45′ − 90° = 33° 45′.
Sine 22° 30′ 9·58284.
Sine 33° 45′ 9·74474.

Sine 12° 16′ 9·32758.

4) For the south pole multiply as above thus; 10 × 20′ = 3′ 20″.

5) Add these degrees to the south angle at London; or 145° 30′ + 2° 25′ + 3° 20′ = 151° 15′.

6) For *oh*;
151° 15′ − 90° = 61° 15′.
Sine 22° 30′ 9·58284.
Sine 61° 15′ 9·94286.

Sine 19° 36′ 9·52570.

7) For *pc*;
41° 9′ + 12° 16′ = 53° 25′.

8) 53° 25′ × 6″ = 5′ 20″.

9) Hence 22′ 30″ + 5′ 20″ = 27′ 50″.

10) For *po*;
180° + 12° 16′ + 19° 36′ = 211° 52′.

11) The square of 180° = 32400 : the square of 211° 52′ = 44900 :: 27′ 50″ : 38′ 45″.

12) By decimal calculation; 38′ 45″ × 53° 25′ = 3° 25′.

13) 22° 30′ + 3° 25′ = 25° 55′, which is the reduced distance.

14) There is no need here of any reduction, but merely subtract 3° 25′ from the true north angle thus; 123° 45′ − 3° 25′ =

120° 20′, which is the apparent north reduced angle, lying to the west, of which the supplement is 59° 40′.

15) For *cd* ;

Sine	41° 9′	9·81824.
Sine	59° 40′	9·93606.
Sine	34° 37′	9·75430.

16) For *ad* ;

Cosine with Radius	59° 40′	19·70331.
Cotangent	41° 9′	10·05854.
Tangent	23° 48′	9·64477.

17) For *bc* first add thus: *ba* + *ad* = *bc*, or 23° 48′ + 25° 55′ = 49° 43′.

Cosine	34° 37′	9·91538.
Cosine	49° 43′	9·81061.
Cosine	57° 52′	9·72599.

18) For the angle *bca* we have the proportion; as 57° 52′, or the side now found, to 59° 40′, or the supplement of the apparent north angle, so is 25° 55′, or the apparent side, to the angle required.

Sine	25° 55′	9·64054.
Sine	59° 40′	9·93606.
		19·57660.
Sine	57° 52′	9·92778.
Sine	26° 28′	9·64882.

Thus we have the side *bc* = 57° 52′, and the angle *bca* = 26° 28′.

We must now find the side and angle at the south pole.

19) For the supplement of the side *oc*; 41° 9′ − 19° 36′ = 21° 23′.

20) By decimal calculation, 21° 23′ × 38′ 45″ = 1° 22′.

21) At this latitude there is no need of reduction.

22) But add 1° 22′ to the true south angle thus; 151° + 1° 22′ = 152° 37′, which is the apparent south reduced angle lying to the west; of which the supplement is 27° 23′.

23) For *nc* :

Sine	41° 9′	9·81824.
Sine	27° 23′	9·66270.
Sine	17° 37′	9·48094.

24) For *nh* ;

Cosine with Radius	27° 23′	19·94838.
Cotangent	41° 9′	10·05854.
Tangent	37° 52′	9·88984.

25) For the side *gc* first subtract thus; 37° 52′ − 25° 55′ = 11° 57′.

Cosine	~~1~~7° 37′	9·97914.
Cosine	11° 57′	9·99048.
Cosine	21° 11′	9·96962.

Its supplement gives the side *gc* = 158° 49′.

26) For the angel *gch* we have the proportion; as 21° 11′, or the side now found, to 27° 23′, the supplement of the apparent

south angle, so is 25° 55′, or the apparent reduced side to the angle required.

Sine 25° 55′ 9·64054.
Sine 27° 23′ 9·66270.

19·30324.
Sine 21° 11′ 9·55793.

Sine 33° 48′ 9·74531.

Thus we have the side $gc = 158°$ 49′, and the angle $gch = 33°$ 48′.

	Sides.	Angles.
27)	57° 52′	26° 28′
	158° 49′	33° 48′
	216° 41′ :	60° 16′

:: 57° 52′ : 16° 0′.

28) If 16° 0′ be subtracted from the north angle, 26° 28′, there remains the declination west 10° 28′.

According to observations it seems to have been 10° 50′, which would show a difference of 0° 22′; but 1709 is placed at 10° 15′; 1710 at 10° 50′; 1711 at 10° 50′; hence between 1709 and 1711, the mean is evidently 10° 28′; so that the annual progression would be 0° 22′.

We have corrected an error in subtraction in section 24, but the angle should be 37° 49′.—*Trs.*

XVI.

Calculation of the Magnetic Declination for the year 1720, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London 2° 25′.

1) Here there are no years intervening, because our calculation begins from 1720; and hence we have only to add the longitude.

2) 112° + 2° 25′ = 114° 25′, so that the true north angle = 114° 25′.

3) For *pa*;
114° 25′ − 90° = 24° 25′.

Sine 22° 30′ 9·58284.
Sine 24° 25′ 9·61633.

Sine 9° 6′ 9·19917.

4) The same remark applies to the south angle: no years intervene, and hence,

5) We have only to add the east longitude; 145° 30′ + 2° 25′ = 147° 55′, which is the true south angle made with the meridian of Paris.

6) 147° 55′ − 90° = 57° 55′.

Sine 22° 30′ 9·58284.
Sine 57° 55′ 9·92802.

Sine 18° 55′ 9·51086.

7) For *pc* ;
41° 9′ + 9° 6′ = 50° 15′.

8) 50° 15′ × 6″ = 5′ 0″.

9) Hence 22′ 30″ + 5′ = 27′ 30″.

10) For *po* ;
180° + 9° 6′ + 18° 55′ = 208° 1′.

11) The square of 180° = 32400 : the square of 208° 1′ = 43264 :: 27′ 30″ : 36′ 45″.

12) By decimal calculation, 36′ 45″ × 50° 15′ = 3° 3′.

13) 22° 30′ + 3° 3′ = 25° 33′, which is the apparent reduced distance.

14) At this latitude there is no need of reduction, but simply subtract 3° 3′ from the true north angle thus: 114° 25′ − 3° 3′ = 111° 22′, which is the apparent north reduced angle lying to the west, of which the supplement is 68° 38′.

15) For *cd* ;
Sine 41° 9′ 9·81824.
Sine 68° 38′ 9·96907.

Sine 37° 47′ 9·78731.

16) For *ad* ;

Cosine with Radius	68° 38′	19·56150.
Cotangent	41° 9′	10·05854.
Tangent	17° 39′	9·50296.

17) For *bc* first add thus ; *ba* + *ad* = *bd*, or 17° 39′ + 25° 33′ = 43° 12′.

Cosine 37° 47′ 9·89781.
Cosine 43° 12′ 9·86271.

Cosine 54° 49′ 9·76052.

18) For the angle *bca* we have the proportion ; as 54° 49′, or the side now found, to 68° 38′, the supplement of the apparent north angle, so is 25° 33′, the apparent reduced distance, to the angle required.

Sine 25° 33′ 9·63477.
Sine 68° 38′ 9·96907.

19·60384.
Sine 54° 49′ 9·91238.

Sine 29° 26′ 9·69146.

Thus we have the side *bc* = 54° 49′ ; and the angle *bca* = 29° 26′.

We must now find the side and angle at the south pole.

19) For the supplement of the side *oc* ; 41° 9′ − 18° 55′ = 22° 14′.

20) By decimal calculation, 36′ 45″ × 22° 14′ = 1° 22′.

21) Here there is no need of reduction.

22) But simply add 1° 22′ to the true south angle thus ; 147° 55′ + 1° 22′ = 149° 17′, which is the apparent south angle of

calculation, at the west: its complement is 30° 43′.

23) For *nc*;

Sine 41° 9′ 9·81824.
Sine 30° 43′ 9·70824.

Sine 19° 38′ 9·52648.

24) For *nh*;

Cosine with Radius	30° 43′	19·93435.
Cotangent	41° 9′	10·05854.
Tangent	36° 55′	9·87581.

25) For the side *gc* first subtract thus; 36° 55′—25° 33′ = 11° 22′.

Cosine 19° 38′ 9·97398.
Cosine 11° 22′ 9·99139.

Cosine 22° 35′ 9·96537.

Its supplement gives the side *cg* = 157° 25′.

26) For the angle *gch* we have the proportion; as 22° 35′, the side now found, to 30° 43′, the supplement of the apparent south angle, so is 25° 33′, the apparent reduced distance, to the angle required.

Sine 25° 33′ 9·63477.
Sine 30° 43′ 9·70824.

19·34301.
Sine 22° 35′ 9·58436.

Sine 35° 0′ 9·75865.

Thus we have the side *gc* = 157° 25′, and the angle *gch* = 35° 0′.

	Sides.	Angles.
27)	54° 49′	29° 36′
	157° 25′	35° 0′
	212° 14′ :	64° 26′

:: 54° 49′ : 16° 38′.

28) If 16° 38′ be subtracted from the north angle, 29° 26′, there remains the declination west, 12° 48′.

According to experiments, the declination in the year 1720, at Paris, seems to have been 13° 0′; making a difference of 0° 12′.

XVII.

Calculation of the Magnetic Declination for the year 1730, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London 2° 25′.

1) 1730 − 1720 = 10; therefore 10 years intervene; hence 10 × 56′ = 9° 20′.

2) Subtract these degrees, but adding the east longitude as before; thus 112° + 2° 25′ − 9° 20′ = 105° 5′; and so 105° 5′ is the true north angle.

3) For *pa*;

$105° 5' - 90° = 15° 5'$.

Sine 22° 30′ 9·58284.

Sine 15° 5′ 9·41534.

Sine 5° 43′ 8·99818.

4) For the south pole, multiply as above; $10 \times 20' = 3° 20'$.

5) Subtract these degrees, and add the longitude to the south angle at London thus; $145° 30' + 2° 25' — 3° 20' = 144° 35'$, which is the true south angle.

6) For *oh*;

$144° 35' - 90° = 54° 35'$.

Sine 22° 30′ 9·58284.

Sine 54° 35′ 9·91113.

Sine 18° 10′ 9·49397.

7) For *pc*;

$41° 9' + 5° 43' = 46° 52'$.

8) $46° 52' \times 6'' = 4' 42''$.

9) Hence $22' 30'' + 4' 42'' = 27' 12''$.

10) For *po*;

$180° + 5° 43' + 18° 10' = 203° 53'$.

11) The square of 180 = 32400 : the square of 203° 53′ = 41616 :: 27′ 12″ : 36′ 30″.

12) By decimal calculation; $36' 30'' \times 46° 52' = 2° 51'$.

13) $22° 30' + 2° 51' = 25° 21'$, which is the apparent reduced distance.

14) At this latitude there is no need of reduction, but simply subtract 2° 51′ from the true north angle: $105° 5' — 2° 51' = 102° 14'$; which is the apparent north reduced angle, at the west; its complement being 77° 46′.

15) For *ch*;

Sine 41° 9′ 9·81824.

Sine 77° 46′ 9·99002.

Sine 40° 1′ 9·80826.

16) For *ad*;

Cosine with Radius	77° 46′	19·32611.
Cotangent	41° 9′	10·05854.
Tangent	10° 29′	9·26757.

17) For *bc* first add thus: $ba + ad = bd$, or $10° 29' + 25° 21' = 35° 50'$.

Cosine 40° 1′ 9·88414.

Cosine 35° 50′ 9·90887.

Cosine 51° 37′ 9·79301.

18) For the angle *bca* we have the proportion; as 51° 37′, the side now found, to 77° 46′, the supplement of the apparent north angle, so is 25° 21′, the apparent reduced distance, to the angle required.

Sine 25° 21′ 9·63159.

Sine 77° 46′ 9·99002.

19·62161.

Sine 51° 37′ 9·89424.

Sine 32° 15′ 9·72737.

Thus we have the side $bc = 51°\ 37'$, and the angle $bca = 32°\ 15'$.

We must now find the side and angle about the south pole.

19) For the supplement of the side oc; $41°\ 9' - 18°\ 10' = 22°\ 59'$.

20) By decimal calculation, $36'\ 20'' \times 22°\ 59' = 1°\ 24'$.

21) At this latitude there is no need of reduction.

22) But add $1°\ 24'$ to the true south angle thus; $144°\ 35' + 1°\ 24' = 145°\ 59'$, which is the apparent south reduced angle at the west; its supplement being $34°\ 1'$.

23) For nc;

Sine 41° 9′	9·81824.
Sine 34° 1′	9·74775.
Sine 21° 36′	9·56599.

24) For nh;

Cosine with Radius	34° 1′	19·91849.
Cotangent	41° 9′	10·05854.
Tangent	35° 55′	9·85995.

25) For the side gc first subtract; $35°\ 55' - 25°\ 21' = 10°\ 34'$.

Cosine 21° 36′	9·96837.
Cosine 10° 34′	9·99257.
Cosine 23° 56′	9·96094.

Its supplement gives the side $cg = 156°\ 4'$.

26) For the angle gch we have the proportion; as 23° 56′, the side now found, to 34° 1′, the supplement of the apparent south angle, so is 25° 1′, or the apparent reduced distance, to the angle required.

Sine 25° 21′	9·63159.
Sine 34° 1′	9·74775.
	19·37934.
Sine 23° 56′	9·60817.
Sine 36° 11′	9·77117.

Thus we have the side $gc = 156°\ 4'$, and the angle $gch = 36°\ 11'$.

	Sides.	Angles.
27)	51° 37′	32° 15′
	156° 4′	36° 11′
	207° 41′ :	68° 26′

:: 51 37° : 16° 58′.

28) If 16° 58′ be subtracted from 32° 15′, there remains the declination west, 15° 17′.

I have not yet been able to learn the declination at Paris for the year 1730, but I do not think there is much difference between it and the result of my calculation. Between the year 1720 and this of 1730, the annual progression appears to have been almost 15 minutes; whence

Years.	Declination. Deg.	Min.	Years.	Declination. Deg.	Min.
1720	12	48	1726	14	18
1721	13	3	1727	14	33
1722	13	18	1728	14	48
1723	13	33	1729	15	2
1724	13	48	1730	15	17
1725	14	3			

XVIII.

Calculation of the Magnetic Declination for the year 1740, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London 2° 25′.

1) 1740 − 1720 = 20; thus 20 years intervene; hence 20 × 56′ = 18° 40′.

2) Subtract these degrees, but add 2° 25′ to the given angle with the meridian of London; 112° + 2° 25′ − 18° 40′ = 95° 45′.

3) For *pa*;

95° 45′ − 90° = 5° 45′.

Sine 22° 30′ 9·58284.

Sine 5° 45′ 8·91807.

Sine 1° 48′ 8·50091.

4) For the south pole multiply as above: 20° × 20′ = 6° 40′.

5) Subtract 6° 40′ from the south angle at London, but add 2° 25′; thus 145° 30′ + 2° 25′ − 6° 40′ = 141° 5′; which is the true south angle at the west.

6) For *oh*;

141° 5′ − 90° = 51° 5′.

Sine 22° 30′ 9·58284.

Sine 51° 5′ 9·89101.

Sine 17° 19′ 9·47385.

7) For *pc*;

41° 9′ + 1° 48′ = 42° 57′.

8) 42° 57′ × 6″ = 4′ 18″.

9) Hence 22′ 30″ + 4′ 18″ = 26′ 48″.

10) For *po*;

180° + 1° 48′ + 17° 19′ = 194° 7′.

11) The square of 180° = 32400 : the square of 194° 7′ = 37636 :: 26′ 48″ : 31′ 20″.

12) By decimal calculation, 31′ 20″ × 42° 57′ = 2° 14′.

13) 22° 30′ + 2° 14′ = 24° 44′, which is the apparent reduced distance.

14) At this latitude there is no need of reduction, but simply subtract 2° 14′ from the true

north angle; $95° 45' - 2° 14' = 93° 21'$, which is the apparent north reduced angle, at the west; its supplement being $86° 29'$.

15) For *cd*;

Sine 41° 9′ 9·81824.
Sine 86° 29′ 9·99918.

Sine 41° 3′ 9·81742.

16) For *ad*;

Cosine with
Radius 86° 29′ 18·78773.
Cotangent 41° 9′ 10·05854.

Tangent 3° 4′ 8·72919.

17) For *bc*, first add; $ba + ad = bd$; or $3° 4' + 24° 44' = 27° 48'$.

Cosine 41° 3′ 9·87745.
Cosine 27° 48′ 9·94673.

Cosine 48° 10′ 9·82418.

18) For the angle *bca* we have the proportion; as 48° 10′, or the side now found, to 86° 29′, or the supplement of the apparent north angle, so is 24° 44′, or the apparent side, to the angle required.

Sine 24° 44′ 9·62158.
Sine 86° 29′ 9·99918.

19·62076.
Sine 48° 10′ 9·87220.

Sine 34° 5′ 9·74856.

Thus we have the side $bc = 48°, 10'$, and the angle $bca = 34° 5'$.

We must now find the side and angle about the north pole.

19) For the supplement of the side *oc*: $41° 9' - 17° 19' = 23° 50'$.

20) By decimal calculation, $23° 50' \times 31' 20'' = 1° 15'$.

21, 22) Here there is no need of reduction, but simply add to the south angle at London thus: $141° 5' + 1° 15' = 142° 20'$, which is the apparent reduced south angle, at the west; its supplement being 37° 40′.

23) For *nc*:

Sine 41° 9′ 9·81824.
Sine 37° 40′ 9·78608.

Sine 23° 42′ 9·60432.

24) For *nh*;

Cosine with
Radius 37° 40′ 19·89849.
Cotangent 41° 9′ 10·05854.

Tangent 34° 40′ 9·83995.

25) For the side *gc* first subtract; $34° 40' - 24° 44' = 9° 56'$.

Cosine 23° 42′ 9·96173.
Cosine 9° 56′ 9·99344.

Cosine 25° 52′ 9·95417.

If we take the supplement, we have the side in question, $gc = 154° 8'$.

26) For the angle *gch* we have

the proportion; as 25° 52′, or the side now found, to 37° 40′, or the supplement of the apparent south angle, so is 24° 44′, or the apparent side, to the angle required.

Sine 24° 44′ 9·62158.
Sine 37° 40′ 9·78608.
―――――
19·40766.
Sine 25° 52′ 9·63976.
―――――
Sine 35° 52′ 9·76790.

Thus we have the side gc = 154° 8′, and the angle gch = 35° 52′.

27) 48° 10′ 34° 5′
154° 8′ 35° 52′
――――― ―――――
202° 18′ : 69° 57′
:: 48° 10′ : 16° 38′.

28) If 16° 38′ be subtracted from the angle, 34° 5′, there remains the declination west 17° 27′.

In section 3, log Sine 5° 45′ is wrong. In section 25 there is an error in the addition of the logs. These errors seriously affect the result.—*Trs.*

XIX.

Calculation of the Magnetic Declination for the year 1750, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London 2° 25′.

1) 1750 − 1720 = 30; thus 30 years intervene; hence 30 × 56′ = 28° 0′.

2) Subtract these degrees, and add the longitude east from London thus: 112° 0′ + 2° 25′ − 28° 0′ = 86° 25′, which is the true north angle to the west.

3) For pa;
90° − 86° 25′ = 3° 35′.

Sine 22° 30′ 9·58284.
Sine 3° 35′ 8·79588.
―――――
Sine 1° 22′ 8·37872.

4) For the south pole multiply as above; 30 × 20′ = 10° 0′.

5) Subtract these degrees from the south angle at London thus; 145° 30′ + 2° 25′ − 10° 0′ = 137° 55′, which is the true south angle at the west.

6) For oh;
137° 55′ − 90° = 47° 55′.

Sine 22° 30′ 9·58284.
Sine 47° 55′ 9·87050.
―――――
Sine 16° 30′ 9·45334.

7) For pc;
41° 9′ − 1° 22′ = 39° 47′.

8) 39° 47′ × 6″ = 3′ 58″.

9) 22′ 30″ + 3′ 58″ = 26′ 28″.

10) For po;
180° + 16° 30′ − 1° 22′ = 194° 38′.

11) The square of 180 = 32400 : the square of 194° 38′ = 37860 :: 26′ 38″ : 31′ 0″.

12) By decimal calculation; $31' \times 39° 47' = 2° 3'$.

13) $22° 30' + 2° 3' = 24° 33'$, which is the apparent reduced distance.

14) There is no need of any reduction at this latitude, but only subtract from the true angle thus: $86° 25' - 2° 3' = 84° 22'$: which is the apparent reduced angle, at the north: nor is there any occasion here for the supplement.

15) For *cd*;

Sine	41° 9′	9·81824.
Sine	84° 22′	9·99789.
Sine	40° 54′	9·81613.

16) For *ad*;

Cosine with Radius	84° 22′	18·99194.
Cotangent	41° 9′	10·05854.
Tangent	4° 34′	8·93340.

17) For *bc* first subtract; $ba - ad = bd$, or $24° 33' - 4° 34' = 19° 59'$.

Cosine	40° 54′	9·87843.
Cosine	19° 59′	9·97303.
Cosine	44° 44′	9·85146.

18) For the angle *bca* we have the proportion; as 44° 44′, or the side now found, to 84° 22′, or the apparent north angle; so is 24° 33′, or the apparent reduced distance, to the angle required.

Sine	24° 33′	9·61855.
Sine	84° 22′	9·99789.
		19·61644.
Sine	44° 44′	9·84745.
Sine	35° 59′	9·76899.

Thus we have the side $bc = 44° 44'$; and the angle $bca = 35° 59'$.

We have now to find, in the same way, the side and angle at the south magnetic pole.

19) For the supplement of the side *oc*; $41° 9' - 16° 30' = 24° 39'$.

20) By decimal calculation; $31' \times 24° 39' = 1° 16'$.

21) There is no need here of any reduction.

22) But simply add 1° 16′ to the true south angle; $137° 55' + 1° 16' = 139° 11'$, which is the apparent reduced south angle, at the west; of which the supplement is 40° 49′.

23) For *nc*;

Sine	41° 9′	9·81824.
Sine	40° 49′	9·81534.
Sine	25° 28′	9·63358.

24) For *nh*;

Cosine with Radius	40° 49′	19·87898.
Cotangent	41° 9′	10·05854.
Tangent	33° 28′	9·82044.

25) For the side *gc* first subtract; $33° 28' - 24° 33' = 8° 55'$.

Cosine 25° 28′ 9·95561.
Cosine 8° 55′ 9·99472.

Cosine 26° 53′ 9·95033.

Its supplement gives the side cg=153° 7′.

26) For the angle gch we have the proportion; as 26° 53′, or the side now found, to 40° 49′, the supplement of the apparent south angle, so is 24° 33′, or the apparent reduced distance, to the angle required.

Sine 24° 33′ 9·61855.
Sine 40° 49′ 9·81534.

19·43389.
Sine 26° 53′ 9·65530.

Sine 36° 55′ 9·77859.

Thus we have the side gc= 153° 7′, and the required angle gch=36° 55′.

27) 44° 44′ 35° 59′
153° 7′ 36° 55′

197° 51′ : 72° 54′
:: 44° 44′ : 16° 30′.

28) If 16° 30′ be subtracted from the north angle, 35° 59′, there remains the declination west, 19° 29′.

In section 16, 4° 34′ should be 4° 54′.—*Trs.*

XX.

Calculation of the Magnetic Declination for the year 1760, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London 2° 25′.

1) 1760 − 1720 = 40; whence 40 years intervene: hence 40 × 56′ = 37° 20′.

2) Subtract these degrees, but add the east longitude; thus 112° 0′ + 2° 25′ − 37° 20′ = 77° 5′, which is the true north angle.

3) For pa;
90° − 77° 5′ = 12° 55′.
Sine 22° 30′ 9·58284.
Sine 12° 55′ 9·34934.

Sine 4° 34′ 8·93218.

4) For the south pole multiply as above thus; 40 × 20′ = 13° 20′.

5) Subtract these degrees, 13° 20′, and add the east longitude thus: 145° 30′ + 2° 25′ − 13 20′

$=134° 35'$, which is the true south angle at the west.

6) For *oh*;

$134° 35' - 90° = 44° 35'$.

Sine	$22° 30'$	9·58284.
Sine	$44° 35'$	9·84630.
Sine	$15° 35'$	9·42914.

7) For *pc*;

$41° 9' - 4° 34' = 36° 35'$.

8) $36° 35' \times 6'' = 3' 39''$.

9) Hence $22' 30'' + 3' 39'' = 26' 9''$.

10) For *po*;

$180° \times 15° 35' - 4° 34' = 191° 1'$.

11) The square of $180° = 32400$: the square of $191° 1'$: : $26' 9''$: $29' 18''$.

12) By decimal calculation, $29' 18'' \times 36° 35' = 1° 51'$.

13) $22° 30' + 1° 51' = 24° 21'$, which is the apparent reduced distance.

14) There is no need here of any reduction, but simply subtract $1° 51'$ from the true north angle; $77° 5' - 1° 51' = 75° 14'$, which is the apparent south angle, placed towards the west. There is no need here of the supplement.

15) For *cd*;

Sine	$41° 9'$	9·81824.
Sine	$75° 14'$	9·98541.
Sine	$39° 31'$	9·80365.

16) For *ad*;

Cosine with

Radius	$75° 14'$	19·40634.
Cotangent	$41° 9'$	10·05854.
Tangent	$12° 33'$	9·34780.

17) For *bc* first subtract; *ba* − *ad* = *bd*; or $12° 33' - 24° 21' = 11° 48'$.

Cosine	$39° 31'$	9·88730.
Cosine	$11° 48'$	9·99072.
Cosine	$40° 57'$	9·87802.

18) For the angle *bca* we have the proportion; as $40° 57'$, or the side now found, to $75° 14'$, the apparent reduced north angle, so is $24° 21'$, or the apparent reduced distance, to the angle required.

Sine	$24° 21'$	9·61522.
Sine	$75° 14'$	9·98541.
		19·60063.
Sine	$40° 57'$	9·81650.
Sine	$37° 28'$	9·78413.

Thus we have the north side $bc = 40° 57'$, and the north angle $bca = 37° 28'$.

We must now find in the same manner the south side and angle.

19) For the supplement of the side *oc*; $41° 9' - 15° 35' = 25° 34'$.

20) By decimal calculation, $29' 18'' \times 25° 34' = 1° 18'$.

21) There is no need of any reduction at this latitude.

22) But simply add 1° 18′ to the true south angle; 134° 35′ + 1° 18′ = 135° 53′, which is the apparent reduced south angle at the west; its supplement is 44° 7′.

23) For *nc*;

Sine	41° 9′	9·81824.
Sine	44° 7′	9·84268.
Sine	27° 16′	9·66092.

24) For *nh*;

Cosine with Radius	44° 7′	19·85607.
Cotangent	41° 9′	10·05854.
Tangent	32° 6′	9·79753.

25) For the side *gc* first subtract thus; 32° 6′ − 24° 21′ = 7° 45′.

Cosine	27° 16′	9·94884.
Cosine	7° 45′	9·99601.
Cosine	28° 16′	9·94485.

Its supplement gives the side *cg* = 151° 44′.

26) For the angle *gch* we have the proportion; as 28° 16′, the side now found, to 44° 7′, the supplement of the apparent south angle, so is 24° 21′, or the apparent reduced distance, to the angle required.

Sine	24° 21′	9·61522.
Sine	44° 7′	9·84268.
		19·45790.
Sine	28° 16′	9·67539.
Sine	37° 18′	9·78251.

Thus we have the side *gc* = 151° 44′, and the angle *gch* = 37° 18′.

27) 40° 57′ 37° 28′
151° 44′ 37° 18′

192° 41′ : 74° 46′ : : 40° 57′ : 15° 54′.

28) If 15° 54′ be subtracted from the angle 37° 28′, there remains the declination west, 21° 34′.

In section 3, 4° 34′ should be 4° 54′.—*Trs.*

XXI.

Calculation of the Magnetic Declination for the year 1770, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London, 2° 25′.

1) 1770 − 1720 = 50; therefore 50 years intervene; hence 50 × 56′ = 46° 40′.

2) Subtract these degrees, and add the east longitude thus; 112° 0′ + 2° 25′ − 46° 40′ = 67°

45′; and therefore 67° 45′ is the true north angle towards the west.

3) For *pa*;
90° − 67° 45′ = 22° 15′.
Sine 22° 30′ 9·58284.
Sine 22° 15′ 9·57823.

Sine 8° 20′ 9·16107.

4) For the south pole multiply as above; 50 × 20′ = 16° 40′.

5) Subtract these degrees, and add the east longitude thus; 145° 30′ + 2° 25′ − 16° 40′ = 131° 15′, which is the true south angle towards the west.

6) For *oh*;
131° 15′ − 90° = 41° 15′.
Sine 22° 30′ 9·58284.
Sine 41° 15′ 9·81911.

Sine 14° 37′ 9·40195.

7) For *pc*;
41° 9′ − 8° 20′ = 32° 49′.

8) 32° 49′ × 6″ = 3′ 15″.

9) Hence 22′ 30″ + 3′ 15″ = 25′ 45″.

10) For *po*;
180° + 14° 37′ − 8° 20′ = 186° 17′.

11) The square of 180 = 32400 : the square of 186° 17′ = 34600 : : 25′ 45″ : 27′ 20″.

12) By decimal calculation, 27′ 20″ × 32° 49′ = 1° 30′.

13) 22° 30′ + 1° 30′ = 24° 0′; which is the apparent side of calculation.

14) There is no need here of any reduction, but only subtract 1° 30′ from the apparent north angle thus; 67° 45′ − 1° 30′ = 66° 15′, which is the apparent north angle of calculation.

15) For *cd*;
Sine 41° 9′ 9·81824.
Sine 66° 15′ 9·96157.

Sine 37° 2′ 9·77981.

16) For *ad*;

Cosine	66° 15′	19·60503.
Cotangent	41° 9′	10·05854.
Tangent	19° 23′	9·54649.

17) For *bc* subtract thus; 24° 0′ − 19° 23′ = 4° 37′.

Cosine	37° 2′	9·90216.
Cosine	4° 37′	9·99858.
Cosine	37° 17′	9·90074.

18) For the angle *bca* we have the proportion; as 37° 17′, the side now found, to 66° 15′, the apparent north reduced angle, so is 24° 0′, the apparent reduced distance, to the angle required.

Sine 24° 0′ 9·60931.
Sine 66° 15′ 9·96159.

19·57090.
Sine 37° 17′ 9·78229.

Sine 37° 56′ 9·78861.

Thus we have the side $bc=37°$ $17'$, and the angle $bca=37° 56'$.

We must now find the side and angle about the south pole.

19) For the supplement of the side *oc*; $41° 9' - 14° 37' = 26° 32'$.

20) By decimal calculation, $27' 20'' \times 26° 32' = 1° 12'$.

21) Here there is no need of reduction.

22) But add 1° 12′ to the true south angle thus; $131° 15' + 1° 12' = 132° 27'$, which is the apparent south reduced angle, at the west, of which the supplement is 47° 33′.

23) For *nc*;

Sine	41° 9′	9·81824.
Sine	47° 33′	9·86797.
Sine	29° 3′	9·68621.

24) For *nh*;

Cosine with Radius	47° 33′	19·82926.
Cotangent	41° 9′	10·05854.
Tangent	30° 32′	9·77072.

25) For the side *gc* first subtract; $30° 32' - 24° 0' = 6° 32'$.

Cosine	29° 3′	9·94161.
Cosine	6° 32′	9·99717.
Cosine	29° 43′	9·93878.

Its supplement gives the required side $gc=150° 17'$.

26) For the angle *gch* we have the proportion; as 29° 43′, the side already found, to 47° 33′, the supplement of the apparent south angle, so is 24° 0′, the apparent reduced distance, to the angle required.

Sine	24° 0′	9·60931.
Sine	47° 33′	9·86797.
		19·47728.
Sine	29° 43′	9·69523.
Sine	37° 15′	9·78205.

Thus we have the side $gc=150°$ $17'$, and the angle $gch=37° 15'$.

27) 37° 17′ 37° 56′
150° 17′ 37° 15′

187° 34′ : 75° 1′
: : 37° 17′ : 14° 48′.

28) If 14° 48′ be subtracted from the angle 37° 56′, there remains the declination west 23° 8′.

In section 15, we have corrected two of the logarithms.—*Trs.*

XXII.

Calculation of the Magnetic Declination for the year 1780, *at Paris.*

North latitude 48° 51′; its complement 41° 9′.

Longitude east from London 2° 25′.

1) $1780 - 1720 = 60$; thus 60 years intervene; hence $60 \times 56' = 56° 0'$.

2) Subtract these degrees and

add the longitude thus; $112° + 2° 25' - 56° = 58° 25'$, which is the true north angle at the west.

3) For *pa*;
$90° - 58° 25' = 31° 35'$.
Sine 22° 30′ 9·58284.
Sine 31° 35′ 9·71911.

Sine 11° 34′ 9·30195.

4) For the south pole multiply as above; $60 \times 20' = 20°$.

5) Subtract 20° 0′, and add the east longitude thus; $145° 30' + 2° 25' - 20° 0' = 127° 55'$, which is the true south angle, at the west.

6) For *oh*;
$127° 55' - 90' = 37° 55'$.
Sine 22° 30′ 9·58284.
Sine 37° 55′ 9·78853.

Sine 13° 36′ 9·37137.

7) For *pc*;
$41° 9' - 11° 34' = 29° 35'$.

8) $29° 35' \times 6'' = 2' 57''$.

9) Hence $22' 30'' + 2' 57'' = 25' 27''$.

10) For *po*;
$180° + 13° 36' - 11° 34' = 182° 2'$.

11) The square of $180° = 32400$: the square of $182° 2' = 33024$: : $25' 27''$: $26' 0''$.

12) By decimal calculation, $26' \times 29° 35' = 1° 17'$.

13) $22° 30' + 1° 17' = 23° 47'$, which is the apparent reduced distance.

14) There is no need of reduction at this latitude, but from the true north angle subtract 1° 17′ thus; $58° 25' - 1° 17' = 57° 7'$; which therefore is the apparent south reduced angle, at the west.

15) For *cd*;
Sine 41° 9′ 9·81824.
Sine 57° 7′ 9·92416.

Sine 33° 33′ 9·74240.

16) For *ad*;

Cosine with Radius	57° 7′	19·73474.
Cotangent	41° 9′	10·05854.
Tangent	25° 23′	9·67620.

17) For *bc* first subtract thus:
$25° 23' - 23° 47' = 1° 36'$.
Cosine 33° 33′ 9·92085.
Cosine 1° 36′ 9·99983.

Cosine 33° 35′ 9·92068.

18) For the angle *bca* we have the proportion: as 33° 35′, the side already found, to 57° 7′, the apparent north angle, so is 23° 47′, the apparent reduced distance, to the angle required.
Sine 23° 47′ 9·60560.
Sine 57° 7′ 9·92416.

19·53976.
Sine 33° 35′ 9·74284.

Sine 38° 48′ 9·79692.

Thus we have the side $bc=33°$ $35'$, and the angle $bca=38°\ 48'$.

We must now find the side and angle about the north pole.

19) For the supplement of the side oc; $41°\ 9'-13°\ 36'=$ $27°\ 33'$.

20) By decimal calculation, $26'\times 27°\ 33'=1°\ 11'$.

21) Here there is no need of reduction.

22) But simply add $1°\ 11'$ to the true south angle thus; $127°$ $55'+1°\ 11'=129°\ 6'$, which is the apparent reduced south angle, at the west; of which the supplement is $50°\ 54'$.

23) For nc;

Sine	41° 9′	9·81824.
Sine	50° 54′	9·88988.
Sine	30° 43′	9·70812.

24) For nh;

Cosine with Radius	50° 54′	19·79980.
Cotangent	41° 9′	10·05854.
Tangent	28° 51′	9·74126.

25) For the side gc first subtract thus: $28°\ 51'-23°\ 47'=$ $5°\ 4'$.

Cosine	30° 43′	9·93435.
Cosine	5° 4′	9·99829.
Cosine	31° 6′	9·93264.

Its supplement gives the side $cg=148°\ 54'$.

26) For the angle gch we have the proportion; as $31°\ 6'$, the side now found, to $50°\ 54'$, the supplement of the apparent south angle; so is $23°\ 47'$, the apparent reduced distance, to the angle required.

Sine	23° 47′	9·60560.
Sine	50° 54′	9·88988.
		19·49548.
Sine	31° 6′	9·71309.
Sine	37° 17′	9·78239.

Thus we have the side $gc=$ $148°\ 54'$, and the angle $gch=37°$ $17'$.

27) $33°\ 35'$ $38°\ 48'$
$148°\ 54'$ $37°\ 17'$

$182°\ 29' : 76°\ 5'$
$:: 33°\ 35' : 13°\ 54'$.

28) If $13°\ 54'$ be subtracted from $38°\ 48'$, there remains the declination west, $24°\ 54'$.

XXIII.

I will now arrange the declinations which have been found by experiments at London and Paris, and those which we have derived from the foregoing calculations; so that we may be able to compare them, and see at one view the whole

series of declinations, particularly those at Paris, from the year 1610 to the year 1680. And since, by the same calculation, I have ascertained the subsequent declinations down to the year 1920, I will add these also. And I see no reason to doubt that experience will bear them out because the calculation is based not only upon theory, but also upon experience itself. I am not indeed vain enough to put forth these speculations, without the sanction and consent of experience; for unless experience imparts her light to theory, the latter will only blind the understanding, and cause it to wander in the mazes of error.

Declinations found at London.

Years.	Calculation.	Observations.
1722	14° 23′ West	14° 22′ West
1700	8° 14′	8° 0′
1692	6° 15′	6° 0′
1735	17° 46′	

Declinations found at Paris.

Years.	By Calculation. Deg. Min.	By Experiments. Deg. Min.	Years.	By Calculation. Deg. Min.	By Experiments. Deg. Min.
1610	8 18 East	8 0 East	1626	5 43	
1611	8 6	There are no	1627	5 37	There are no
1612	7 54	experiments	1628	5 31	experiments
1613	7 42	for these years.	1629	5 25	for these years.
1614	7 30		1630	5 19	
1615	7 19		1631	5 9	
1616	7 8		1632	5 0	
1617	6 57		1633	4 50	
1618	6 45		1634	4 40	
1619	6 33		1635	4 29	
1620	6 41		1636	4 19	
1621	6 15		1637	4 9	
1622	6 8		1638	3 59	
1623	6 1		1639	3 48	
1624	5 55		1640	3 36	3 0 East
1625	5 49		1641	3 28	

Years.	By Calculation. Deg. Min.	By Experiments. Deg. Min.	Years.	By Calculation. Deg. Min.	By Experiments. Deg. Min.
1642	3 20		1677	2 57	
1643	3 12		1678	3 7	
1644	3 5		1679	3 18	
1645	2 57		1680	3 29	2 40
1646	2 50		1681	3 41	2 30
1647	2 43		1682	3 53	
1648	2 36		1683	4 5	3 50
1649	2 29		1684	4 17	4 10
1650	2 21		1685	4 29	4 10
1651	2 10		1686	4 41	4 30
1652	1 59		1687	4 53	
1653	1 48		1688	5 5	
1654	1 37		1689	5 17	
1655	1 26		1690	5 30	
1656	1 15		1691	5 41	
1657	1 4		1692	6 1	5 50
1658	0 53		1693	6 17	6 20
1659	0 42		1694	6 34	
1660	0 31		1695	6 51	6 48
1661	0 20		1696	7 7	7 8
1662	0 10		1697	7 24	
1663	0 —		1698	7 40	7 40
1664	0 10 West	0 40 East	1699	7 56	8 10
1665	0 20		1700	8 12	8 12
1666	0 32	0 0	1701	8 26	8 25
1667	0 47		1702	8 39	8 48
1668	1 3		1703	8 53	9 6
1669	1 19		1704	9 6	9 20
1670	1 35	1 30 West	1705	9 20	9 35
1671	1 46		1706	9 33	9 48
1672	1 58		1707	9 47	10 10
1673	2 10		1708	10 1	10 15
1674	2 21		1709	10 15	10 15
1675	2 33		1710	10 28	10 50
1676	2 46		1711	10 42	10 50

Years.	By Calculation. Deg.	Min.	By Experiments. Deg.	Min.
1712	10	56	11	15
1713	11	10	11	12
1714	11	24	11	30
1715	11	38	11	10
1716	11	52	12	20
1717	12	6	12	20
1718	12	20	12	30
1719	12	34	12	30
1720	12	48	13	0
1721	13	3	13	0
1722	13	18	13	0
1723	13	33	13	0
1724	13	48	13	0
1725	14	3	13	15
1726	14	18	13	45
1727	14	33	14	0
1728	14	48	14	0
1729	15	2		
1730	15	17		
1731	15	30		
1732	15	43		
1733	15	56		
1734	16	9		
1735	16	22		
1736	16	35		
1737	16	48		
1738	17	1		
1739	17	14		
1740	17	27		
1741	17	40		
1742	17	53		
1743	18	5		
1744	18	17		
1745	18	29		
1746	18	41		

Years.	By Calculation. Deg.	Min.
1747	18	53
1748	19	5
1749	19	17
1750	19	29
1751	19	42
1752	19	55
1753	20	8
1754	20	21
1755	20	34
1756	20	46
1757	20	58
1758	21	10
1759	21	22
1760	21	34
1761	21	44
1762	21	54
1763	22	4
1764	22	13
1765	22	23
1766	22	31
1767	22	40
1768	22	49
1769	22	58
1770	23	8
1771	23	19
1772	23	30
1773	23	41
1774	23	52
1775	24	3
1776	24	14
1777	24	24
1778	24	34
1779	24	44
1780	24	54
1781	25	5

Years.	By Calculation. Deg.	Min.	Years.	By Calculation. Deg.	Min.
1782	25	5	1818	16	30
1783	24	58	1819	15	50
1784	24	48	1820	15	19
1785	24	40	1821	14	30
1786	24	30	1822	13	50
1787	24	20	1823	13	10
1789	24	12	1824	12	30
1790	24	2	1825	11	40
1791	23	56	1826	10	50
1792	23	50	1827	10	0
1793	23	44	1828	9	10
1794	23	38	1829	8	25
1795	23	32	1830	7	38
1796	23	26	1831	6	40
1797	23	20	1832	5	50
1798	23	14	1833	5	0
1799	23	8	1834	4	10
1800	23	3	1835	3	0
1801	22	50	1836	2	2
1802	22	34	1837	1	0
1803	22	16	1838	0	0
1804	21	54	1839	1	0 East
1805	21	36	1840	2	0
1806	21	18	1841	3	0
1807	21	0	1842	4	0
1808	20	42	1843	5	0
1809	20	34	1844	6	0
1810	20	12	1845	7	0
1811	19	50	1846	8	0
1812	19	25	1847	9	0
1813	19	0	1848	10	0
1814	18	38	1849	11	0
1815	18	4	1850	12	4
1816	17	30	1851	13	6
1817	17	0	1852	14	9

Years.	By Calculation. Deg.	Min.
1853	15	12
1854	16	15
1855	17	12
1856	18	0
1857	18	50
1858	19	45
1859	20	40
1860	21	32
1861	22	20
1862	23	0
1863	23	40
1864	24	20
1865	25	0
1866	25	40
1867	26	20
1868	27	0
1869	27	40
1870	28	18
1871	28	44
1872	29	10
1873	29	36
1874	30	2
1875	30	28
1876	30	54
1877	31	20
1878	31	56
1879	32	21
1880	32	45
1881	33	0
1882	33	20
1883	33	40
1884	33	55
1885	34	8
1886	34	20

Years.	By Calculation. Deg.	Min.
1887	34	32
1888	34	42
1889	34	52
1890	35	4
1891	35	14
1892	35	23
1893	35	32
1894	35	40
1895	35	47
1896	35	52
1897	35	59
1898	36	6
1899	36	13
1900	36	21
1901	36	22
1902	36	23
1903	36	24
1904	36	25
1905	36	26
1906	36	27
1907	36	28
1908	36	29
1909	36	30
1910	36	31
1911	36	28
1912	36	25
1913	36	22
1914	36	19
1915	36	16
1916	36	13
1917	36	10
1918	36	7
1919	36	4
1920	36	0

The declinations thus follow in order according to the calculation, of which I trust experience will be the test and confirmation. It is to be observed, that from this point the declination will again descend, and very gradually, through not less than 130 years, before it returns to the west; but in its ascent it will make very large and considerable strides. It may, therefore, be concluded, if only calculation and experience agree, as I trust they do, that there is no certain annual progression of the declinations, but that at one time they pass annually through an entire degree, at another through scarcely a single minute; the difference consisting in the relation to the different situation of the poles. In other places, as for instance near the south and north poles, the annual declination describes still further degrees.

It is also to be observed, that the declinations at Paris can scarcely be greater than about 37 degrees, and this, very rarely; nor will the period when this is the case recur oftener perhaps than once in 20 or 30 ages.

With respect to the agreement between the observations and my own calculation, I find in some instances a difference of 35, 30, 20, 10, or 5 minutes, and in some cases no difference. But as no one except the observer himself can know in what way the declination was taken; in what way the meridian was found; whether or not it was in the most exact line and parallel with the real meridian of the place; what kind of magnet was used; what was the division of degrees; what the parallelism of the side of the instrument with the meridian line; whether magnetic or iron particles were moving in the vicinity; whether the wind or air disturbed the tranquillity of the needle; whether the needle was moveable and horizontal upon its pivot, and had no hindrance, or tendency to stick fast. As no one can know all these facts, and yet all are possible, and generally do occur in experimenting, it is, therefore, impossible that the declinations calculated should coincide absolutely with the declinations observed. Let us now proceed to the calculation of the declinations in other places.

XXIV.

Calculation of the Magnetic Declination for the year 1670, *at Rome.*

North latitude 41° 50′; its complement 48° 10′.

Longitude east from London, 14° 13′.

1) 1720 − 1670 = 50 : thus 50 years intervene; hence 50 × 56′ = 46° 40′.

2) Add these degrees together with the east longitude thus; 112° 0′ + 46° 40′ + 14° 13′ = 172° 53′, the true north angle towards the west.

3) For *pa*;
172° 53′ − 90° = 82° 53′.
Sine 22° 30′ 9·58284.
Sine 82° 53′ 9·99664.

Sine 22° 19′ 9·57948.

4) For the south pole multiply as above; 50 × 20′ = 16° 40′.

5) Add these degrees together with the east longitude thus; 145° 30′ + 16° 40′ + 14° 13′ = 176° 23′, which is the true south angle towards the west.

6) For *oh*;
176° 23′ − 90′ = 86° 23′.
Sine 22° 30′ 9·58284.
Sine 86° 23′ 9·99913.

Sine 22° 27′ 9·58197.

7) For *pc*;
48° 10′ + 22° 19′ = 70° 29′.

8) 70° 29′ × 6″ = 7′ 3″.

9) Hence 22′ 30″ + 7′ 3″ = 29′ 33″.

10) For *po*;
180° + 22° 19′ + 22° 27′ = 224° 46′.

11) The square of 180° = 32400 : the square of 224° 46′ = 50600 : : 29′ 33″ : 46′ 0″.

12) By decimal calculation, 46′ × 70° 29′ = 5° 24′.

13) 22° 30′ + 5° 24′ = 27° 54′, which is the reduced distance.

14) At this latitude, of 41° 50′, there is need of reduction: it answers in the table to 44°; hence there will be the proportion, 60° : 44° : : 5° 24′ : 3° 58′.

Subtract 3° 58′ from the true north angle thus; 172° 53′ − 3° 58′ = 168° 55′, which is the apparent north reduced angle situated to the west, of which the supplement is 11° 5′.

15) For *cd*;
Sine 48° 10′ 9·87220.
Sine 11° 5′ 9·28383.

Sine 8° 14′ 9·15603.

16) For *ad*;

Cosine with
Radius 11° 5′ 19·99182.
Cotangent 48° 10′ 9·95189.

Tangent 47° 38′ 10·03993.

17) For the side bc first add thus; 47° 38′+27° 54′=75° 32′.

Cosine 8° 14′ 9·99550.
Cosine 75° 32′ 9·39762.

Cosine 75° 41′ 9·39312.

18) For the angle bca we have the proportion, as 75° 41′, or the side now found, to 11° 5′, the supplement of the apparent north angle, so is 27° 54′, the apparent reduced distance, to the angle required.

Sine 27° 54′ 9·66802.
Sine 11° 5′ 9·28383.

18·95185.
Sine 75° 41′ 9·98629.

Sine 5° 18′ 8·96556.

Thus we have the side bc=75° 41′; and the angle bca=5° 18′.

We must now find the side and angle at the south pole.

19) For the supplement of the side oc; 48° 10′−22° 27′=25° 43′.

20) By decimal calculation, 46′×25° 43′=1° 57′.

21) Make here the reduction as above, 60° : 44° :: 1° 57′ : 1° 26.′

22) Add 1° 26′ to the true south angle thus; 176° 23′+1° 26′=177° 49′, which is the apparent south reduced angle, situated at the west, of which the supplement is 2° 11′.

23) For nc;

Sine 48° 10′ 9·87220.
Sine 2° 11′ 8·58089.

Sine 1° 38′ 8·45309.

24) For nh;

Cosine with
Radius 2° 11′ 19·99968.
Cotangent 48° 10′ 9·95189.

Tangent 48° 9′ 10·04779.

25) For the side gc first subtract thus; 48° 9′−27° 54′=20° 15′.

Cosine 1° 38′ 9·99982.
Cosine 20° 15′ 9·97229.

Cosine 20° 19′ 9·97211.

Its supplement gives the side gc=159° 41′.

26) For the angle gch there will be the proportion, as 20° 19′, or the side already found, to 2° 11′, or the supplement of the apparent south angle, so is 27° 54′, or the apparent reduced distance, to the angle required.

Sine 27° 54′ 9·66802.
Sine 2° 11′ 8·58089.

18·24891.
Sine 20° 19′ 9·54059.

Sine 2° 55′ 8·70832.

Thus we have the side gc= 159° 41′, and the angle gch= 2° 55′.

27) 75° 41′ 5° 18′
159° 41′ 2° 55′

235° 22′ : 8° 13′
: : 75° 41′: 2° 38′.

28) If 2° 38′ be subtracted from 5° 18′, there remains declination west, 2° 40′.

According to observations, the declination was 2° 30′; whence there is a difference of only 0° 10′, as compared with Musschenbroek. Auzout observed at Rome, in the year 1670, that the declination was either 2° or 2° 30′ towards the west; as recorded in the *Philosophical Transactions*, vol. v. p. 1184. But Rome lies 11° 48′ east of Paris; so that the declination towards the west was greater at Rome than at Paris in the same year.

In sections 18 and 26, log. Sin. 27° 54′ is wrongly given.—*Trs.*

XXV.

Calculation of the Magnetic Declination for the year 1672, *at Uraniborg.*

North latitude 55° 54′; its complement 34° 6′.

Longitude east from London, 13° 0′.

1) 1720 − 1672 = 48; thus 48 years intervene; and $48 \times 56' =$ 44° 48′.

2) Add 44° 48′ together with the east longitude thus; 112° 0′ + 13° 0′ + 44° 48′ = 169° 48′, which is the true north angle situated at the west.

3) For pa;
169° 48′ − 90° = 79° 48′.
Sine 22° 30′ 9·58284.
Sine 79° 48′ 9·99308.

Sine 20° 38′ 9·57592.

4) For the south pole multiply as above thus; $48 \times 20' =$ 16° 0′.

5) Add these degrees, 16° 0′, together with the east longitude, thus; 145° 30′ + 16° 0′ + 13° 0′ = 174° 30′.

6) For oh;
174° 30′ − 90° = 84° 30′.
Sine 22° 30′ 9·58284.
Sine 84° 30′ 9·99709.

Sine 20° 49′ 9·57993.

7) For pc;
34° 6′ + 20° 38′ = 54° 44′.

8) 54° 44′ × 6″ = 5′ 30″.

9) 22′ 30″ + 5′ 30″ = 28′ 0″.

10) For po;
180° + 20° 38′ + 20° 49′ = 221° 27′.

11) The square of 180=32400 : the square of 221° 27′=49040 : : 28′ : 42′ 20″.

12) By decimal calculation, 42′ 20″ × 54° 44′=3° 53′.

13) 22° 30′+3° 53′=26° 23′, which is the apparent reduced distance.

14) Make the reduction or increase, according to the table at this latitude, 60° : 77° : : 3° 53′ : 4° 59′.

Subtract 4° 59′ from the true north angle or arc ; 169° 48′ – 4° 59′=164° 49′ ; which is the apparent north angle or reduced arc, at the west ; of which the supplement is 15° 11′.

15) For *cd* ;

Sine	34° 6′	9·74868.
Sine	15° 11′	9·41815.
Sine	8° 27′	9·16683.

16) For *ad* ;

Cosine	15° 11′	19·98453.
Cotangent	34° 6′	10·16937.
Tangent	33° 9′	9·81516.

17) For the side *bc* first add ; 33° 9′+26° 23′=59° 32′.

Cosine	8° 27′	9·99526.
Cosine	59° 32′	9·70504.
Cosine	59° 54′	9·70030.

18) For the angle *bca* we have the proportion, as 59° 54′, or the side already found, to 15° 11′, the supplement of the apparent north arc, so is 26° 23′, the apparent reduced distauce, to the angle required.

Sine	26° 23′	9·64775.
Sine	15° 11′	9·41815.
		19·06590.
Sine	59° 54′	9·93709.
Sine	7° 44′	9·12881.

Thus we have the side *bc*=59° 54′, and the angle *bca*=7° 44′.

We must now find the side and angle at the south pole.

19) For the supplement of the side *oc*; 34° 6′ – 20° 49′=13° 17′.

20) By decimal calculation, 42′ 20″ × 13° 17′=0° 54′.

21) Make the reduction or increase, 60° : 77° : : 0° 54′ : 1° 9′.

22) Add 1° 9′ to the true south arc, 174° 30′ × 1° 9′ = 175° 39′, which is the apparent south reduced arc, situated at the west, of which the supplement is 4° 21′.

23) For *nc* ;

Sine	34° 6′	9·74868.
Sine	4° 21′	8·87995.
Sine	2° 26′	8·62863.

24) For *nh* ;

Cosine with Radius	4° 21′	19·99874.
Cotangent	34° 6′	10·16937.
Tangent	34° 1′	9·82937.

25) For the side *gc* first sub-

tract thus: 34° 1′ − 26° 23 = 7° 38′.

Cosine	2° 26′	9·99961.
Cosine	7° 38′	9·99613.
Cosine	8° 1′	9·99574.

Its supplement gives the side *gc* = 171° 59′.

26) For the angle *gch* we have the proportion, as 8° 1′, or the side now found, to 4° 21′, the supplement of the apparent south arc, so is 26° 23′, or the apparent reduced distance, to the angle required.

Sine	26° 23′	9·64775.
Sine	4° 21′	8·87995.
		18·52770.
Sine	8° 1′	9·14445.
Sine	13° 59′	9·38325.

Thus we have the side *gc* = 171° 59′, and the angle *gch* = 13° 59′.

	Sides.	Angles.
27)	59° 54′	7° 44′
	171° 59′	13° 59′
	231° 53′ :	21° 43′

:: 59′ 54° : 5° 36′.

28) If 5° 36′ be subtracted from 7° 44′, there remains the declination west, 2° 8′.

The observation in tab. VI. indicates the declination in that year to have been 2° 35′; whence there is a difference of 0° 27′.

In section 3, the last Sine is wrong, and in section 6, the logs of the last two Sines are wrongly taken.—*Trs*

XXVI.

On a voyage to Hudson's Straits in the years 1721 *and* 1725; *longitude west from London,* 41° 0′; *north latitude,* 55° 0′.

The north latitude is 55° 0′; its complement 35° 0′; west longitude 41° 0′.

1) 1725 − 1720 = 5; thus five years intervene; hence 5 × 56′ = 4° 40′.

2) Subtract these degrees, and likewise the longitude (since it is west); 112° 0′ − 4° 40′ − 41° 0′ = 66° 20, which is the true north angle.

3) For *pa*; 90° − 66° 20′ = 23° 40′.

Sine	22° 30′	9·58284.
Sine	23° 40′	9·60359.
Sine	8° 50′	9·18643.

4) For the south pole multiply as above; whence 5 × 20′ = 1° 40′.

5) Subtract 1° 40′, together with the west longitude thus;

145° 30′ − 1° 40′ − 41′ 0′ = 102° 50′, which is the true south angle, to the west.

6) For *oh*;

102° 50′ − 90° = 12° 50′.

Sine	22° 30′	9·58284.
Sine	12° 50′	9·34658.
Sine	4° 53′	8·92942.

7) For *pc*;

35° 0′ − 8° 50′ = 26° 10′.

8) 26° 10′ × 6″ = 2′ 36″.

9) 22′ 30′ + 2′ 36 = 25′ 6″.

10) For *po*;

180° − 8° 50′ − 4° 53′ = 166° 17′.

11) The square of 180 = 32400 : the square of 166° 17′ = 27000 :: 25′ 6″ : 21′ 0″.

12) By decimal calculation, 21′ 0″ × 26° 10′ = 0° 54.′

13) 22° 30′ + 0° 54′ = 23° 24′, which is the apparent reduced distance.

14) Make the reduction or increase at this latitude; 60° : 74° :: 8° 54′ : 1° 6′. Hence subtract 1° 6′ from the true north angle; 66° 20′ − 1° 6′ = 65° 14′, which is the apparent north reduced angle, situated at the west.

15) For *cd*;

Sine	35° 0′	9·75859.
Sine	65° 14′	9·95809.
Sine	31° 23′	9·71668.

16) For *ad*;

Cosine with Radius	65° 14′	19·62213.
Cotangent	35° 0′	10·15477.
Tangent	16° 21′	9·46736.

17) For *bc* first subtract; 23° 24′ − 16° 21′ = 7° 3′.

Cosine	31° 23′	9·93130.
Cosine	7° 3′	9·99670.
Cosine	32° 6′	9·92800.

18) For the angle *bca* we have the proportion, as 32° 6′, the side now found, to 65° 14′, the apparent north angle, so is 23° 24′, the apparent reduced distance, to the angle required.

Sine	23° 24′	9·59895.
Sine	65° 14′	9·95809.
		19·55704.
Sine	32° 6′	9·72542.
Sine	42° 44′	9·83162.

Thus we have the side *bc* = 32° 6′, and the angle *bca* = 42° 44′. We must now find the side and angle at the south pole.

19) For the supplement of the side *oc*; 35° 0′ − 4° 53′ = 30° 7′.

20) By decimal calculation, 21′ 0″ × 30° 7′ = 1° 3′.

21) Make the reduction or increase; 60° : 74° :: 1° 3′ : 1° 17′.

22) Add 1° 17′ to the true south angle; 102° 50′ + 1° 17′ =

104° 7′, which is the apparent south reduced angle, situated at the west; of which the supplement is 75° 53′.

23) For *nc*;

Sine 35° 0′ 9·75859.
Sine 75° 53′ 9·98668.

Sine 33° 48′ 9·74527.

24) For *nh*;

Cosine	75° 53′	19·38720.
Cotangent	35° 0′	10·15477.
Tangent	9° 42′	9·23243.

25) For the side *gc* first subtract; 23° 24′ − 9° 42′ = 13° 42′.

Cosine	33° 48′	9·91959.
Cosine	13° 42′	9·98746.
Cosine	36° 10′	9·90705.

Its supplement gives the side *gc* = 143° 50′.

26) For the angle *gch* we have the proportion, as 36° 10′, the side now found, to 75° 53′, the supplement of the apparent south angle, so 23° 54′, the apparent reduced distance, to the angle required.

Sine	23° 24′	9·59895.
Sine	75° 53′	9·98668.
		19·58563.
Sine	36° 10′	9·77095.
Sine	40° 44′	9·81468.

Thus we have the side *gc* = 143° 50′, and the angle *gch* = 40° 44′.

	Sides.	Angles.
27)	32° 6′	42° 44′
	143° 50′	40° 44′
	175° 56′ :	83° 28′

:: 32° 6′ : 15° 11′.

28) If 15° 11′ be subtracted from 42° 44′, there remains the declination west, 27° 33′.

According to the observations in table XII., the declination seems to have been 28° 15′; whence there is a difference of 0° 42′, which may easily be accounted for at sea, especially as the true year is not given.

XXVII.

Calculation of the Magnetic Declination at the Sebald Islands, at the eastern entrance into the Straits of Magellan, in the year 1707.

South latitude 52° 0′; its supplement 38° 0′.

Longitude west from London 70°.

1) 1720 − 1707 = 13; thus 13 years intervene: hence 13 × 56′ = 12° 8′.

2) Add these degrees, and subtract the longitude; 112° 0′ + 12° 8′ − 70° = 54° 8′, which

is the true north angle at the west.

3) For *pa*;

$90° - 54°\ 8' = 35°\ 52'$.

Sine 22° 30′ 9·58284.

Sine 35° 52′ 9·76782.

Sine 12° 57′ 9·35066.

4) For the south pole multiply as above thus; $13 \times 20' = 4°\ 20'$.

5) Add 4° 20, but subtract the longitude thus; $145°\ 30' + 4°\ 20' - 70° = 79°\ 50'$, which is the true south angle at the west.

6) For *oh*;

$90° - 79°\ 50' = 10°\ 10'$.

Sine 22° 30′ 9·58284.

Sine 10° 10′ 9·24677.

Sine 3° 52′ 8·82961.

7) For *pc*;

$52° + 90° - 12°\ 57' = 129°\ 3'$.

8) $129°\ 3' \times 6'' = 12'\ 54''$.

9) $22'\ 30'' + 12'\ 54'' = 35'\ 24'$.

10) For *po*;

$180° - 12°\ 57' - 3°\ 52' = 163°\ 11'$.

11) The square of 180° = 32000 : the square of 163° 11′ = 26580 :: 35′ 24″ : 29′ 0″.

12) By decimal calculation, $29'\ 0'' \times 129°\ 3' = 6°\ 14'$.

13) $22°\ 30' + 6°\ 14' = 28°\ 44'$, which is the apparent reduced distance.

14) Make the reduction or increase, 60° : 67° :: 6° 14′ : 6° 57′. Subtract these degrees from the true north angle thus; $54°\ 8' - 6°\ 57' = 47°\ 11'$; which gives the apparent north reduced angle, situated at the west.

15) For *cd*;

Sine 38° 0′ 9·78934.

Sine 47° 11′ 9·86542.

Sine 26° 50′ 9·65476.

16) For *ad*;

Cosine with

Radius	47° 11′	19·83228.
Cotangent	38° 0′	10·10719.
Tangent	27° 58′	9·72509.

17) For the side *bc* first add thus; $27°\ 58' + 28°\ 27' = 56°\ 25'$.

By logarithms:

Cosine	26° 50′	9·95052.
Cosine	56° 25′	9·74284.
Cosine	60° 26′	9·69336.

Its supplement gives the side $bc = 119°\ 34'$.

18) For the angle *bca* we have the proportion; as 60° 26′, the side already found, to 47° 11′, the apparent north angle, so is 28° 27′, or the apparent reduced distance, to the angle required.

Sine 28° 27′ 9·67796.

Sine 47° 11′ 9·86542.

19·54338.

Sine 60° 26′ 9·93941.

Sine 23° 41′ 9·60397.

Thus we have the side bc= 119° 34′; and the angle bca= 23° 41′.

We must now find the side and angle at the south pole.

19) For the side oc;
90° 0′+52° 0′+3° 52′=145° 52.′

20) By decimal calculation, 29′ 0″ × 145° 52′=7° 3′.

21) Make the reduction or increase, 60° : 67° :: 7° 3′ : 7° 52′.

22) Add 7° 52′ to the true south angle; 79° 50′ 7° 52′= 87° 42′, which is the apparent south reduced angle at the west.

23) For nc;

Sine	38° 0′	9·78934.
Sine	87° 42′	9·99965.
Sine	37° 58′	9·78899.

24) For nh;

Cosine with Radius	87° 42′	18·60348.
Cotangent	38° 0′	10·10719.
Tangent	1° 48′	8·49629.

25) For the side gc first subtract; 28° 27′ – 1° 48′=26° 39′. By logarithms:

Cosine	37° 58′	9·89673.
Cosine	26° 39′	9·95122.
Cosine	45° 12′	9·84795.

26) For the angle gch we have the proportion; as 45° 12′, the side already found, to 87° 42′, the apparent south reduced angle, so is 28° 27′, the apparent reduced distance, to the angle required.

Sine	28° 27′	9·67796.
Sine	87° 42′	9·99965.
		19·67761.
Sine	45° 12′	9·85099.
Sine	42° 8′	9·82662.

Thus we have the side gc=45° 12′, and the angle gch=42° 8′.

	Sides.	Angles.
27)	119° 34′	23° 41′
	45° 12′	42° 8′
	164° 46′ :	65° 49′

: 119° 34′ : 47° 47′.

28) If 23° 41′ be subtracted from 47° 47′, there remains the declination west, 24° 6′.

According to observations, in the years 1706, 1707, and 1708, (tab. XXIV. XXV. XIV.,) the declination seems to have been east 23° 0′ : 23′ 5°, at Sebald's Islands.

But it is to be observed that Feüillée, in tab. XIV.,[1] for the year 1708, states the declination to be east 23° 0′, at south latitude 53°, but at longitude 315° 29′ from Teneriffe, or

[1] See above, p. 41.

about 66° from London; with which longitude also the declination 23° 0′ coincides, but nearer toward the entrance the declination is greater; according to the calculation, 24° 6′.

Verune observed, (tab. XXIV.,) in the year 1706, at south latitude 52° 19′, and west longitude 70°, or 69½°, that the declination was about 23°, which also nearly agrees with our calculation.

In Dampier's voyage, (tab. XXV.,) in the year 1707, near the Waard Islands, the declination was found to be 23° 0′, but at south latitude 51° 25′; with which also coincides 23° 0′, but at a higher latitude, for instance, at 52° 0, as in the calculation, it will be greater, and in fact about 24°.

Johann Baptist Homann [1] and others, place the Sebald Islands in their geographical maps, at longitude west from London, about 70° or 69½°, but at latitude 51°; with which coincides the declination 23° 0′; but at latitude 52° 0′, it will be 24° 0′.

In order then that the true place of the observation may be obtained, the latitude must be 51° south, and the longitude about 69°; with which the declination 23° will evidently coincide, according to the calculation.

XXVIII.

Calculation of the Magnetic Declination at the Cape of Good Hope, for the year 1600.

South latitude 35° 0′; its supplement 55° 0′.

Longitude east from London, about 20°.

1) 1720 − 1600 = 120: thus 120 years intervene: hence 120 × 56′ = 112° 0′.

2) Add these degrees to the north angle at London, in the year 1720, together with the longitude (because it is east) thus; 112° 0′ + 20° 0′ + 112° 0′ = 244°. Subtract 244° from 360°, and the remainder, 116°, is the true north angle placed at the east.

[1] Homann published his map in the year 1716. Modern geographers place the Falkland Islands between 51 and 53 lat. S., and between 57 and 62 long. W.—*Trs.*

3) For *pa*;

$116° \ 0' - 90° = 26° \ 0'$.

Sine 22° 30′ 9·58284.

Sine 26° 0′ 9·64184.

Sine 9° 39′ 9·22468.

4) For the south pole multiply as above; $120 \times 20' = 40°$.

5) Add 40° together with the east longitude thus; $145° \ 30' \times 40° \ 0' + 20° \ 0' = 205° \ 30'$. Subtract 205° 30′ from 360°; and the remainder, 154° 30′, is the true south angle situated at the east.

6) For *oh*;

$154° \ 30' - 90° = 64° \ 30'$.

Sine 22° 30′ 9·58284.

Sine 64° 30′ 9·95548.

Sine 20° 12′ 9·53832.

7) For *pc*;

$35° \ 0' + 90° \ 0' + 9° \ 39' = 134° \ 39'$.

8) $134° \ 39' \times 6'' = 13' \ 27''$.

9) $22' \ 30'' + 13' \ 27'' = 35' \ 57''$.

10) For *po*;

$180° + 9° \ 39' + 20° \ 12' = 209° \ 51'$.

11) The square of $180° = 32400$: the square of $209° \ 51' = 44000$: : 35′ 57″ : 48′ 30″.

12) By decimal calculation, $48' \ 30'' \times 134° \ 39' = 10° \ 50'$.

13) $22° \ 30' + 10° \ 50' = 33° \ 20'$, which is the apparent reduced side.

14) Make the reduction for this latitude; 60° : 30° : : 10° 50′ : 5° 25′; add 5° 25′ to the true north angle thus; $116° \ 0' + 5° \ 25' = 121° \ 25'$; (the addition being made because the north pole is now on the east), which is the apparent north reduced angle situated at the east; its supplement is 58° 35′.

15) For *cd*;

Sine 55° 0′ 9·91336.

Sine 58° 35′ 9·93115.

Sine 44° 21′ 9·84451.

16) For *ad*;

Cosine with Radius	58° 35′	19·71705.
Cotangent	55° 0′	9·84522.
Tangent	36° 40′	9·87183.

17) For the side *bc* first subtract; $36° \ 40' + 33° \ 20' = 3° \ 20'$. By logarithms:

Cosine	44° 21′	9·85435.
Cosine	3° 20′	9·99926.
Cosine	44° 27′	9·85361.

Its supplement gives the side in question, 135° 33′.

18) For the angle *bca* we have the proportion; as 44° 27′, the side now found, to 58° 35′, the supplement of the apparent north angle, so is 33° 20′, the apparent reduced distance, to the angle required.

Sine 33° 20′ 9·73997.
Sine 58° 35′ 9·93115.

19·67112.
Sine 44° 27′ 9·84527.

Sine 42° 2′ 9·82585.

Thus we have the side *bc*= 135° 33′; and the angle *bca*= 42° 2′.

We must now find the side and angle at the south pole.

19) For the side *oc*;
90° 0′ + 35° 0′ − 20° 12′ = 104° 48′.

20) By decimal calculation, 48′ 30″ × 104° 48′ = 8° 24′.

21) Make the reduction according to the table, at this latitude, 60° : 30° : : 8° 24′ : 4° 12′.

22) Subtract 4° 12′ from the true south angle, 154° 30′ − 4° 12′ = 150° 18′, which is the apparent south reduced angle situated at the west, of which the supplement is 29° 42′.

23) For *nc*;
Sine 55° 0′ 9·91336.
Sine 29° 42′ 9·69500.

Sine 23° 57′ 9·60836.

24) For *nh*;
Cosine with
Radius 29° 42′ 19·93883.
Cotangent 55° 0′ 9·84523.

Tangent 51° 8′ 10·09360.

25) For the side *gc* first add;
51° 8′ + 33° 20′ = 84° 28′.
Cosine 23° 57′ 9·96089.
Cosine 84° 28′ 8·98418.

Cosine 84° 57′ 8·94507.

26) For the angle *bca* we have the proportion; as 84° 57′, the side already found, to 29° 42′, the supplement of the apparent south angle, so is 33° 20′, or the apparent reduced distance, to the angle required.

Sine 33° 20′ 9·73997.
Sine 29° 42′ 9·69500.

19·43497.
Sine 84° 57′ 9·99831.

Sine 15° 51′ 9·43666.

	Sides.	Angles.
27)	135° 33′	42° 2′
	84° 57′	15° 51′
	220° 30′	57° 53′

220° 30′ : 57° 53′ : : 135° 33′ : 36° 19′.

28) If 36° 19′ be subtracted from 42° 2′, there remains the declination east, 5° 43′.

But some assert that in the year 1600, there was no declination at the Cape of Good Hope. Kircher, however, in tab. i., states that 26 leagues

from the Cape of Good Hope there was a declination east of 4° 0′; whether, therefore, observers have determined the true year or not, is still doubtful.

In section 24, we have put Cotangent and Tangent where original has Sine.—*Trs.*

XXIX.

Calculation of the Magnetic Declination for the year 1675, *at the Cape of Good Hope.*

South latitude 35° 0′; its complement 55° 0′.

Longitude east from London, about 20°.

1) 1720 − 1675 = 45: thus 45 years intervene; hence 45 × 56′ = 42° 0′.

2) Add these degrees, together with the longitude, which is east, thus; 112° 0′ + 20° 0′ + 42° 0′ = 174° 0′, which is the true north angle situated at the west.

3) For *pa*;
174° 0′ − 90° = 84° 0′.
Sine 22° 30′ 9·58284.
Sine 84° 0′ 9·99761.

Sine 22° 22′ 9·58045.

4) For the south pole multiply as above; 45 × 20′ = 15° 0′.

5) Add these degrees, together with the longitude; 145° 30′ + 20° + 15° = 180° 30′; which if subtracted from 360°, leaves 179° 30′, which is the true north angle, situated at the east.

6) For *oh*;
179° 30′ − 90° = 89° 30′.
Sine 22° 30′ 9·58284.
Sine 89° 30′ 9·99998.

Sine 22° 30′ 9·58282.

7) For *pc*;
35° 0′ + 90° 0′ + 22° 22′ = 147° 22′.

8) 147° 22′ × 6″ = 14° 44′.

9) 22° 30′ + 14° 44′ = 37° 14′.

10) For *po*;
180° + 22° 22′ + 22° 30′ = 224° 52′.

11) The square of 180 = 32400 : the square of 224° 52′ = 50600 : : 37′ 14″ : 57′ 47″.

12) By decimal calculation, 57′ 47″ × 147° 22′ = 14° 10′.

13) 22° 30′ + 14° 10′ = 36° 40′, which is the apparent reduced distance.

14) Make the reduction here according to the Table; 60° : 30° : : 14° 10′ : 7° 5′. Subtract these degrees (7° 5′) from the true north angle thus; 174° 0′ − 7° 5′ = 166° 55′, which is the

apparent north reduced angle, situated at the west, of which the supplement is 13° 5′.

15) For *cd*;

Sine 55° 0′ 9·91336.
Sine 13° 5′ 9·35481.

Sine 10° 41′ 9·26817.

16) For *ad*;

Cosine with
Radius 13° 5′ 19·98857.
Cotangent 55° 0′ 9·84522.

Tangent 54° 17′ 10·14335.

17) For the side *bc* first subtract thus; 54° 17′ − 36° 40′ = 17° 37′.

Cosine 10° 41′ 9·99240.
Cosine 17° 37′ 9·97914.

Cosine 20° 31′ 9·97154.

Its supplement gives the side *bc* = 159° 29′.

18) For the angle *bca* we have the proportion, as 20° 31′, the side now found, to 13° 5′, the supplement of the apparent north angle, so is 36° 40′, or the apparent reduced distance, to the angle required.

Sine 36° 40′ 9·77609.
Sine 13° 5′ 9·35481.

19·13090.
Sine 20° 31′ 9·54466.

Sine 21° 43′ 9·58624.

Thus we have the side *bc* = 159° 29′, and the angle *bca* = 21° 43′.

We must now find the side and angle at the south pole.

19) For the side *oc*;

35° 0′ + 90° 0′ − 22° 30′ = 102° 30′.

20) By decimal calculation, 57′ 47″ × 102° 30′ = 9° 50′.

21) At this latitude make the proper reduction, 60° : 30° : : 9° 50′ : 4° 55′.

22) Subtract 4° 55′ from the true south angle, as the pole is at the east side; 179° 30′ − 4° 55′ = 174° 35′, which is the apparent south reduced angle, situated at the east; its supplement is 5° 25′.

23) For *nc*;

Sine 55° 0′ 9·91336.
Sine 2° 25′ 8·62496.

Sine 1° 59′ 8·53832.

24) For *nh*;

Cosine with
Radius 2° 25′ 19·99961.
Cotangent 55° 0′ 9·84522.

Tangent 54° 58′ 10·15439.

25) For the side *gc* first add thus; 54° 58′ + 36° 40′ = 91° 38′; its supplement is 88° 22′.

Cosine 1° 59′ 9·99974.
Cosine 88° 22′ 8·45489.

Cosine 88° 22′ 8·45463.

Its supplement gives the side in question, 91° 38′.

26) For the angle *gch* we have the proportion, as 88° 22′, the side now found, to 5° 25′, the supplement of the apparent north angle, so is 36° 40′, the apparent reduced distance, to the angle required.

Sine 36° 40′ 9·77609.
Sine 5° 25′ 8·97496.

18·75105.
Sine 88° 22′ 9·99982.

Sine 3° 14′ 8·75123.

Thus we have the side $gc=91°$ 38′, and the angle $gch=3°$ 14′.

	Sides.	Angles	
27)	159° 29′	21° 43′	
	91° 38′	3° 14′	difference
	251° 7′ :	18° 29′	
	: : 159° 29′ :	11° 44′.	

28) If 11° 44′ be subtracted from 21° 43′, there remains the declination west, 9° 59′.

In Leydekker's table xiii.,[1] the declination was observed, at east longitude 41° 14′ and at south latitude 38° 25′, to be 11° 30′; and in tab. vi., on the promontory of Aguillas, near the Cape of Good Hope, at latitude 34° 50′, to be 8° 0′, in both cases in the year 1675: whence the declination seems to have been 9° 59′ at the Cape of Good Hope.

In section 18, the angle required should be 22° 41′.—*Trs.*

XXX.

Calculation of the Magnetic Declination for the year 1720, *at the Cape of Good Hope.*

South latitude 35° 0′; its supplement 55° 0′.

Longitude east from London, about 20°.

1) No years intervene in this case.

2) Hence we have only to add the longitude, because it is east, thus; 112° 0′+20° 0′=132° 0; which is the true north angle situated at the west.

3) 132° 0′−90°=42° 0′, for *pa*.

Sine 22° 30′ 9·58284.
Sine 42° 0′ 9·82551.

Sine 14° 50′ 9·40835.

4) In this case there is no

[1] See above, p. 129.—*Trs.*

need of multiplication for the south pole.

5) But only add the longitude, because it is east; $145° 30' + 20° 0' = 165° 30'$, which is the true south angle situated at the west.

6) For *oh*;
$165° 30' - 90° = 75° 30'$.
Sine 22° 30′ 9·58284.
Sine 75° 30′ 9·98594.

Sine 21° 45′ 9·56878.

7) For *pc*;
$35° 0' + 90° 0' + 14° 50' = 139° 50'$.

8) $139° 50' \times 6'' = 14° 0'$.

9) $22' 30'' + 14' 0'' = 36' 30''$.

10) $180° + 14° 50' + 21° 45' = 216° 35'$, for *po*.

11) The square of 180 = 32400 : the square of 216° 35′ = 46800 : : 36′ 30″ : 52′ 0″.

12) By decimal calculation, $52' \times 139° 50' = 12° 8'$.

13) $22° 30' + 12° 8' = 34° 38'$, which is the apparent reduced distance.

14) Make here the proper reduction, 60° : 30° : : 12° 8′ : 6° 4′; and by subtracting 6° 4′ from the true north angle ($132° 0' - 6° 4' = 125° 56'$), we have the apparent north reduced angle, situated at the west, of which the supplement is 54° 4′.

15) For *cd*;
Sine 55° 0′ 9·91336.
Sine 54° 4′ 9·90832.

Sine 41° 33′ 9·82168.

16) For *ad*;

Cosine with Radius	54° 4′	19·76852.
Cotangent	55° 0′	9·84522.
Tangent	39° 58′	9·92330.

17) For the side *bc* first subtract; $39° 58' - 34° 38' = 5° 20'$.
Cosine 41° 33′ 9·87412.
Cosine 5° 20′ 9·99811.

Cosine 41° 50′ 9·87223.

Its supplement gives the side in question *bc* = 138° 10′.

18) For the angle *bca* we have the proportion, as 41° 50′, the side now found, to 54° 4′, the supplement of the apparent north angle, so is 34° 38′, the apparent reduced distance, to the angle required.
Sine 34° 38′ 9·75459.
Sine 54° 4′ 9·90832.

19·66291.
Sine 41° 50′ 9·82410.

Sine 43° 38′ 9·83881.

Thus we have the side *bc* = 138° 10′, and the angle *bca* = 43° 38′.

We must now find the side and angle at the south pole.

19) For the side *oc*;
125° 0′ − 21° 45′ = 103° 15′.

20) By decimal calculation, 52′ × 103° 15′ = 8° 55′.

21) Make the reduction proper at this latitude, 60 : 30° : : 8° 55′ : 4° 28′.

22) Add 4° 28′ to the true south angle; 165° 30′ + 4° 28′ = 169° 58″, which is the apparent south reduced angle, situated at the west; of which the supplement is 10° 2′.

23) For *nc*;

Sine	55° 0′	9·91336.
Sine	10° 2′	9·24110.
Sine	8° 12′	9·15446.

24) For *nh*;

Cosine with Radius	10° 2′	19·99330.
Cotangent	55° 0′	9·84522.
Tangent	54° 35′	10·14808.

25) For the side *gc* first add: 54° 35′ + 34° 38′ = 89° 13′.

Cosine	8° 12′	9·99553.
Cosine	89° 13′	8·13581.
Cosine	89° 13′	8·13134.

26) For the angle *gch* we have the proportion, as 89° 13′, the side now found, to 10° 2′, the apparent south reduced angle, so is 34° 38′, or the apparent reduced distance to the angle required.

Sine	34° 38′	9·75459.
Sine	10° 2′	9·24140.
		18·99569.
Sine	89° 13′	9·99995.
Sine	5° 41′	8·99574.

Thus we have the side *gc* = 89° 13′, and the angle *gch* = 5° 41′.

	Sides.	Angles.
27)	138° 10′	43° 38′
	89° 13′	5° 41′
	227° 23′ :	49° 19′

: : 138° 10′ : 29° 47′.

28) If 29° 47′ be subtracted from 43° 38′, there remains the declination west, 13° 51′.

From tab. xvii. in the year 1718, at the Cape of Good Hope, the declination west seems to have been 14° 0′; whence there is a difference of 0° 9′.

END OF PART II.

PART III.

CHAPTER I.

COMPARISON OF THE STARRY HEAVEN WITH THE MAGNETIC SPHERE.

NATURE is always the same, and identical with herself. If in the least things she is most perfectly geometrical, so also is she in the greatest. That which is most perfect in a smaller form gives rise to nothing dissimilar to itself, and consequently there is nothing dissimilar to it in the larger. All dissimilarity implies imperfection. Were nature dissimilar to herself in her larger productions, there would be something imperfect in her least productions, and this would also generate something dissimilar. But since in the first entity, as in the natural point for instance, every thing is most perfectly geometrical, so the same perfection is continued even to the greatest entity; that is to say, similarity is maintained throughout. The infinite itself is the cause and origin of the whole finite world and universe: this infinite is a unity in which greater or less can have no existence, and in which there are simultaneously all things that ever can be. According to our idea, what is infinitely great and what is infinitely small are, as it were, two things; but because the infinite is in the highest perfection and most perfectly identical, it follows that such as it is in its greatest, such also it is in its least entity; nor is it possible to think of an intermediate between the greatest and the least in the infinite. According to our finite senses we are apt to conceive that the finite is intermediate, stretching in the infinite from the least to the greatest; but because what is finite is as nothing in respect to

what is infinite, the intermediate between them must also be regarded as respectively nothing; so that in the infinite the greatest and least entity are one and the same. For a finite difference between two infinites implies no other state in the infinite than that of its being one and the same. Nature, the offspring of the infinite, derives from its origin this property also, that it is most perfectly similar to itself, for the reason that nothing imperfect or dissimilar can spring from the infinite. Since however nature is finite, it follows that in the state of perfection and similarity to herself to which we have referred, she derives this peculiarity and this only, as it were, from herself, that she is susceptible of degrees and times, of dimensions, modes, ends, and boundaries, and also of variety in her state, which is not the case with the infinite.

With respect to the nature and series of finites we observe that man is introduced into the world and its mechanical order, as an intermediate between its least and greatest things; for his senses perceive such things as are, in general, equidistant from the extremes of nature. He does not comprehend everything that lies around him. His wonder is excited both by what he sees and by what he does not see. Wherever he looks he is filled with astonishment, one extreme of nature being above his senses, the other being below them; he aspires, however, to a knowledge of both. Now since nature is most perfectly identical with herself, both in what is greatest and what is least, we may, from what we see and feel, arrive at a knowledge of what we neither see nor feel. Thus has nature designed that we should be instructed through the medium of the senses. But man possesses a soul as well as senses; and the soul has the power to reason and analyse, so that by reasoning and analysis, or by comparison of similar things, we may arrive at some knowledge of those things which do not come within the scope of the senses.

The magnet and the play of its forces we both see and we do not see; hence our wonder at the phenomena it presents. In the magnet and its sphere there is, however, a type and image

of the heavens; a world-system in miniature presented to our senses and brought within the limits of our comprehension. In the sphere of the magnet are spiral gyrations or vorticles; and in the starry heavens there are spiral gyrations and vortices. In every vorticle round the magnet there is an active centre; in every vortex in the heavens there is also an active centre. In every vorticle round the magnet motion is more rapid near the centre than at a distance from it; the same is the case in every vortex in the heavens. In every vorticle round the magnet the spiral gyration has a greater curvature in proportion to its nearness to the centre; the same is the case with every vortex in the heavens. In every vorticle round the magnet there are probably minute particles moving about the centre and revolving round an axis; such also is the case with every vortex in the heavens. The vorticles round the magnet are mutually associated by their spiral motions, and, thus associated, they form a larger sphere; the same is the case in the starry heaven;—not to mention other points of agreement of which we shall speak in the sequel. All things are similar one to another, because in minute as well as in large things nature maintains the greatest similarity to herself; especially as the vorticles moving round the magnet possess particles and elements of the same nature as the vortices of the vast heavens, and because these vortices are similar, as well as their causes, therefore the effects produced are similar.

Now because man is endowed both with an upright carriage in order that he may look upward to the heavens, and with a soul derived from the aura of a better world, in virtue of which he is allied to heaven, let us raise our thoughts, and from the study of a common magnetic stone ascertain the nature of that which is on the greatest scale and is both visible and invisible. Let the mind thus soar into the vastest regions of the universe; and, as much as in it lies, while confined to the body, enjoy the wonders of the heavens above. Perhaps some one may say—Supposing we do, what then? Shall we become the wiser?—Well, we are but finite beings, and the objects we survey are themselves but finite. Our wisdom, therefore, will be but that

of finite man; wisdom derived from a knowledge of finite things, which must itself be consequently finite, and which therefore in relation to the wisdom of the Infinite is nothing. What then? The end of our wisdom must be to admire the Infinite who is the Author of the finite universe, as we admire the maker of a piece of mechanism.

1. The elements both active and passive, treated of in the first part of our *Principia*, act on a small scale in the same way as on a large one; in a volume, in the same way as in a system; in a vorticle round the magnet, as in a great vortex round the sun. They act in the same way whether the active centre be an insignificant emanation constantly moving round its axis, or whether it be a large and constantly moving solar centre. In the heavens or finite universe there may be innumerable vortices of this kind, if there are innumerable active centres; or there may be as many vortices as there are suns or stars.

For these elements are the primary, the most universal, the most simple, and are not subject to much modification; hence they are fluent in a vorticle, the same as in a vortex; in a volume, the same as in a system; and round an effluvial particle in the same manner as round the sun. Since the element is the same, and since the cause is the same and similar, it follows that the same motive force and the same nature prevail in the largest as in the least entity; and, as we have before observed, it is the same in the things above our senses as in those below them.

2. With regard to the motion of each vortex, it follows from the parallelism and similarity between the vortices of the magnet and those of the starry heaven, that the motion of each vortex is from the active or solar centre to the circumferences; but that the motion towards the equators of the parts is not similar to the motion toward their poles, by reason of the geometrical difference in the figure of each part. In consequence of this difference of motion, the formation of the spiral gyrations is toward the poles and axes of the parts; that is to say, in the larger system, toward the poles of the zodiac. The spiral gyrations have a greater curvature in proportion to their proximity

to the centre of motion or to the sun or star; and the farther they are, the less is their curvature. The spiral motion which takes place according to the poles or axes of the parts, is expanded and unfolded into one more and more rectilinear, till at length it terminates in a common or rectilinear or parallel arrangement of the parts. These propositions, being the same as those which I have stated in the first chapter of part ii., when treating of the magnet, it will be unnecessary here to enter into further explanation.

3. We have also the following. Two solar or stellar vortices are more closely associated by the spirals nearer to the centre than by those more remote, as is evidently the case with the magnetic vorticles; they may be associated either at a great or at a small distance; they may be reciprocally associated if one axis is opposed to another, but not if one equator is opposed to another; association as to the poles is direct, but association of the poles with the equators of the parts is indirect and oblique; there is no association as to the equators of the parts, that is to say, in the large vortex, as to the zodiac; the centres of motion or the various suns and stars may thus be at greater or less distances from one another. If there are several in a smaller space or at a smaller distance, the gyration of one is not disturbed by that of the other. To prove this would be only to repeat what we have before stated.

4. The active, solar, or stellar spaces in the middle of the vortex are there in their own natural locality; they cannot be removed out of the vortex; the centre is indivisible and inseparable from the vortex, and the vortex from the centre; one follows the other; and there cannot be two or more suns, stars or active spaces, in one vortex.

5. Further, one vortex with its active centre constitutes one heaven of itself or one mundane system; several vortices with their centres form together a certain sphere. A sphere consisting of many vortices of the same kind has its own proper figure, and the figure of every sphere its own proper axis. The vortices bend their course in every direction from one axis, and

curve it toward another; round this other axis they bend their course in a similar manner, whence by the association of the vortices the sphere passes on to another axis; the sphere is so associated with its axis, that all the vortices in the entire sphere have a reference to the axes, so that no vortex can be moved out of its place, unless the figure, connection, order, and course of the whole sphere be in some measure disturbed. Vortices are larger in proportion to their greater distance from the axis as also along the axis. The whole visible starry heaven is one large sphere, and its suns or stars, together with their vortices, are parts of a sphere connected one with another in the way we have mentioned.

6. The axes of the vorticles in this sphere are variously bent or curved, and all the elementary particles in this sphere have the same arrangement as the vortices themselves, or the sphere itself; hence the vortices, as well as all the elementary particles in the axes themselves, are spheres having a rectilinear disposition; but those extending from the axes have a curvilinear arrangement, or one which is bent relatively to the axes. We have before shown that the elementary particles have the same arrangement as the vorticles, or that the arrangement of these particles is according to the figure of the sphere. For if there is a vortical motion among the elementary particles, and if one vortex is conjoined with another by means of its motion, then it is conjoined as to its spires; and because the spires flow at first in a direction almost at right angles with and afterwards in one more inclined to the axis of the parts, as represented in fig. 1 (vol. i., p. 239), the parts also must necessarily be brought into the same arrangement; that is to say, they will be adapted, together with their vortices, to the same situation. If there is a parallelism of the gyrating volumes, there must be a parallelism of the parts; such as is the conjunction of the vortices, such is that of the parts. The general motion and situation cannot be contrary to the motion and arrangement of the parts; for, according to our rule, the motion of the volume is the motion of the parts, and contrariwise. Thus the order of the one determines the order of the other. It is only by similarity of situation that equilibrium

and association are obtained and preserved. Suppose a number of cylinders jumbled together, and one general motion be originated among them, every particular cylinder will at length accommodate itself to this motion. The arrangement of all, when in motion, will become synchronous : one cannot lie in a direction transverse to the other, or be moved in a direction transverse to the motion of the other : the general motion tends to equilibrium by means of the arrangement and conformably to the figure of the parts. Further, if we communicate a motion to other and similar cylinders, and reciprocally apply to each other or conjoin the two volumes of cylinders thus in motion, they will arrange themselves according to the mechanism of their motions ; as will also the parts of the volumes. The reciprocal application of the parts gives to the volume its perpetuity of motion. According to our thesis, therefore, it follows that in a sphere of the same kind all the elementary particles bring themselves into the same arrangement as the vortices, or into the same as that occupied by the sphere ; that consequently the vortices, as also all the elementary particles in the axis of the sphere, have a rectilinear arrangement ; but that from the axis they are bent into a curvilinear arrangement or one which is inflected in regard to the axis. It therefore follows that the elementary particles in the whole of this sphere or starry heaven, do not look to one and the same pole, except in the axis of the sphere only ; that all the vortices or mundane systems which are in this axis have the same poles, and that all the vortices or systems out of this axis have not the same poles, but that the poles are according to the arrangement of the systems in the sphere.

7. There may thus be axes variously inflected, according to the application of neighbouring or surrounding vortices. If the axis of a vortex be inflected, the spiral gyrations according to the equators of the parts or zodiac of the vortex are not circular but elliptical. The active centre cannot be in the middle of the vortex, but is in one of its foci. If the axis be variously bent, then at various distances from the centre there are various ellipses, or there are various eccentricities relatively

to the active centre. The planets move elliptically in a vortex of this kind, the axis of which is variously inflected; and their sun is not in the middle or centre of the vortex, but situated variously in one of the foci. Of these principles we have already treated in chap. i. of part ii. From what we have said above, it also follows that the arrangement of the parts is according to the application of the vortices; or that in the axis the figure of the sphere is rectilinear; but round the axis, inflected. If, now, the arrangement of the parts is inflected, then the vortical or spiral motion terminates itself in a similar arrangement; in this case not in a rectilinear but curvilinear arrangement, yet still in an ultimate parallelism of the parts.

Let us now see what sort of vortical motion takes place in a volume, when the axes of the parts do not lie in a right line. When they lie in a right line, then all the spiral motion toward the equators is circular; the centre itself is always in the middle, for the motion flows in a regular manner, because it terminates in a rectilinear arrangement of the parts. When, however, they lie in a curvilinear direction, the motion extends itself indeed on every side immediately toward the equators of the parts, but in such a manner as to terminate in a parallel, and, in this case, a curvilinear arrangement of the parts; consequently the motion is not of a circular, but of an elliptical or other figure; nor can its centre be in the middle of the figure. The more inflected the situation of the parts, the more does the rotation change from the circular into some other figure; the more does it on one side recede from the centre, and on the other approach to it.

If we describe a curve inflected inwardly on every side, and at any given points of the curve erect perpendiculars or diameters, and upon these describe circles, the diameters or circles will on one side of the curve approximate more closely to one another, while on the other side they will be more widely separated. At one extremity of a diameter drawn perpendicularly to the surface of the curve, the distance to the centre or point of inflection will be less than it is at the other extremity. Similarly if spiral circles be described perpendicularly or obliquely to the inflected

axis, the distances from the centre will be different according to the different curvature of the axis: the greater the curvature of the axis, the greater will be the distance from the centre on one side than on the other; while on the other hand, the less the curvature, the less will be the difference of the distance to the centre on either side. The figure of rotation, therefore, depends upon the arrangement of the parts; the more eccentric the rotation, the more curvilinear the arrangement of the parts. The curvature of the arrangement of the parts arises from the application of the neighbouring vortices. If the vortices be applied to each other, at their axes or equators, the more may the arrangement of the parts be inflected; the parts and also the gyrations are inflected at the same angle and distance in which the neighbouring vortices are applied; so that there exist different bendings of the parts and of the rotations at different distances from the centre, consequently different ellipses and eccentricities. We shall explain in the sequel, how the planets, equilibrated and moving in a vortex of this kind, follow the vortical current, and describe the same figure. We must bear in mind that the axis of every vortex equals the whole width of the vortex, as we have shown in chap. i., part ii. We, therefore, have the following. All the vortices which are directly in the axis of the sphere or sidereal heaven, are not inflected as to their axes; but their rotations are spirally circular, and their centre is in the middle; but round the axis, where they begin to be circumflected, their rotations are elliptical, and their active centre is, in this case, not in the middle; hence there are different and numerous eccentricities. Consequently our solar vortex is not in the axis of the sphere, but is near the axis where there is a considerable curvature or inflection.

8. The common axis of the sphere or starry heaven seems to be the galaxy, where we perceive the greatest number of stars. Along the galaxy all the vortices are in a rectilinear arrangement and series, and cohere as to their poles; in like manner, they are there more intimately associated, and have spires of greater curvature. The other solar or stellar vortices afterwards pro-

ceed from the axis, and are bent in different directions; but nevertheless all have reference to that axis. This is a consequence of the preceding observations. For the greater the number of active centres in the same space, the closer and more interior is the association of the spirals. Their greatest number is in the milky way, and there also their reciprocal conjunction is the strongest. For this reason the ancients believed the palace and hall of their deities to be there. When the gods ascended into heaven, they went by this path and across this arch, and each passed to his own halls and his own kingdom. For here lies the chain and magnetic course of the whole of our sidereal heaven.

9. No change can occur in one vortex, which is not in some measure felt in an adjacent vortex, as well as in all the rest, even to the axis, and, therefore, throughout the entire sphere. For the vortices seem to be mutually associated like those round the magnet, and it is by reason of connection that a sphere continues to subsist. The vortices in connection with one another are only parts; parts preserve the connection: if one part is deficient, there is a corresponding deficiency in the connection: if one link in a chain is removed, lengthened, or shortened, all the links of the chain alter their position: if one link is moved from its place, the whole chain is moved with it; for taken collectively they form one connected body: all the parts taken together are the causes of the intimate association of part with part. If you prick a nerve or artery in an animal, all the nerves and neighbouring arteries are immediately sensible of it. Hence, in consequence of the vortices being in series and connection, no change can happen in one which is not felt in the other. If the least part is wanting in a regular figure, there no longer remains the same degree of resistance.

10. We, therefore, have the following. From a given eccentricity and elliptic figure at different distances from the centre, the skilful geometrician may infer the situation of the neighbouring vortices, and the curvatures of the axis; while, on the other hand, from the given situation and distance of the neighbour-

ing vortices, and the curvatures of the axes, or from the arrangements of the parts, he may infer what spiral rotation may exist at different distances. Thus from given ellipses or orbits of the planets, he may know the curvatures of the axis, as also the situation of the neighbouring vortices, together with various other particulars.

11. There may be innumerable spheres of this kind or starry heavens in the finite universe. These may be associated one with the other, like the spheres of two magnets; and the whole visible starry heaven is perhaps but a point in respect to the universe. The objects comprehended within the range of our bodily vision are perhaps few; the greater number can be comprehended only by the mind. This very starry heaven, stupendous as it is, forms, perhaps, but a single sphere, of which our solar vortex constitutes only a part; for this universe is finited in the infinite. Possibly there may be other spheres without number, and other heavens without number similar to those we behold; so many indeed and so mighty, perhaps, that our own may be respectively only a point; for all the heavens, however many, however vast, yet being but finite, and consequently having their bounds, do not amount even to a point in comparison with the infinite. Consequently if all the spheres, if all the heavenly hosts are not even a point in respect to the infinite; if the whole visible starry expanse, which to our eyes appears so immense, is only as a point in relation to the finite universe; if our solar vortex forms only a small part of the heavens, and our own world only a small part of the solar vortex, what should man think of himself? Can he be such as he imagines himself to be? Vainglorious mortal, why so inflated with self-importance? Why deem all the rest of creation beneath thee? Diminutive worm, why art thou so puffed up with pride, when thou beholdest around thee a creation so vast—so stupendous? If thou considerest thyself, insignificant one that thou art, and comparest, how trifling a part of heaven and earth thou must appear to be! Thou canst be great only in this that thou art able to adore Him who is the greatest and the Infinite.

CHAPTER II.

THE DIVERSITY OF WORLDS.

In our former chapters we have amply explained the universe and its laws, such as they are or may be. We now proceed another step, and enquire whether nature can extend her bounds still further. She is most fertile and equally ambitious; for she is never at rest, but always desirous to advance and to extend the bounds of her dominion; indeed the more fertile she is, the greater are her efforts. She extends her forces and her sway into infinity, in which there are neither boundaries nor ends, and where she may continue to multiply without end. She detracts in no way from the infinite by her multiplications; nor can she claim for herself anything of the infinite; for the infinite is without end; proceed as far as she may, yet, in respect to the infinite, she is nothing; and the infinite always remains the infinite. Nor can she relatively equal or occupy a point of the infinite. Hence new heavens one after the other may arise; in these heavens, new vortices and world-systems; in these world-systems, new planets; around the planets, new satellites; and in this manner, at the will of the Deity, new creations may arise in endless succession. How many myriads of heavens, therefore, may there not be, how many myriads of world-systems! And if in one heaven or celestial sphere there may be myriads of these, how vast must be the number of the planets with their satellites, especially in comparison with the number of heavens! Indeed, geometry is lost in attempting the calculation. Now, no one will deny that these heavens and world-systems have come into existence as the result of causes acting in time and successively; nor is there reason why we should not suppose that at the will of the Deity fresh systems may come into being every moment; for this is possible.

If now they do come into existence, and by the same causes, contingencies, and changes as those by which our planet came into being, we may also conjecture that each earth in its infancy would be similar to ours in its infancy; that in this primary state, every thing upon its surface would be in the flower of youth, and would, so to speak, smile and be full of gladness. This infantile and genial character would manifest itself in the mineral, vegetable, and animal kingdoms; and thus the golden age would extend its reign throughout every part of the universe, especially when the sun himself would be still in his youth, and such a world as ours existed in its first youth full of delights of every kind. In a word, the coming into existence of infant heavens and earths is possible, when others are beginning to become old and fall into decay. From a possibility, however, we cannot reason to actuality; for when the mind indulges in conjecture, it may lose itself in the regions of immensity. If, however, there is an animal kingdom, of the same kind as our own, in these worlds, then we must also suppose that there are the same contingencies and changes, the same modifications and series of existing things, even to the same degree of perfection as our own world; but since we cannot presume that, in these respects, other worlds are absolutely similar to our own, so we cannot assert that a new world is peopled with inhabitants of a kind similar to those here. Let us, however, proceed from conjectures to realities.

1. No world can exist, rich in the variety of its phenomena, without first passing through a succession of states and of intervals of time; through a succession of changes and contingencies; through modes or modifications; through series of successive, simultaneous, and coexisting phenomena; also through connections of series, and repeated separations and connections; whence arises the perfection of its compositions. This conclusion we may arrive at a priori and a posteriori; from first principles, and from phenomena. Nothing can come into existence without a mode; nothing can undergo a modification without a contingent: no contingent can exist without

changes to which it must be subject either before or at the moment of existence. There can be no change except among composite entities, and those which preëxist; no entities can preëxist unless there are causes; no causes can bring anything into act, except by means of contingencies and changes. We return by a circle to the first simple, in the primitive force of which all entities are latent. Variety is the perfection of the world. If there had been only one or two kinds of elements, other things, such as ether, air, fire, and many others would not have come into existence. Without ether, there would be no light; no rays distinguished by degrees of shade; no beautiful variety of colours, no visual organs adapted to receive them, and share their pleasurable impressions with the soul. If there were no air, there would be no undulation to set the tympanum of the ear in harmonic motion; neither voice nor articulate sound; neither melody nor harmony to soothe the senses and the soul; no breath for the lungs; there would consequently be no animal or animal kingdom; no human being, except one devoid of every sense, and lower than the brute.

Again, in regard to the mineral kingdom, without a series of things existing successively and simultaneously, it would be entirely void, or provided only with things of the simplest kind. There would not be so many kinds of salts, stones, and earths, argillaceous, and much less metallic, substances; things would have no relative value, because there would be neither difference nor variety among them. The mineral kingdom is itself an effigy of the changes which took place during the formation of the earth; and the earth affords abundant proof of this wherever it is penetrated. For if we descend even to the reputed regions of Tartarus and Pluto, we nowhere find in the course of our passage any one thing absolutely like another; we are always meeting with something new, something different; and the many new and diverse substances met with are indications of changes that have taken place. Consider the vegetable kingdom; how varied it is, how pleasing, how delightful because of this variety. And the vegetable kingdom is so varied because

of the mineral kingdom from which its roots and very essence spring. What a pleasing variety meets the eye! There is not a grassy field that is not supplied with abundance of seed; not a piece of turf in it which is not rich in fruitfulness; comparatively few places are undiversified by herbs or grasses, or flowers of some kind, delighting and satisfying the senses both of sight and smell. If we pass through groves, woods, and forests, one may well say with the poet, that every grave is pregnant with future birth. It is the same with the animal kingdom, which takes its origin from the three former; namely, from the elementary, without which no animal could breathe, neither the eye nor the ear perceive anything, nor could any motion so quickly pass from the senses to the inward soul to announce changes occurring in the elements; in a word, without the elementary kindgom there would be no life. The animal kingdom originates also from the vegetable, by which it must be nourished, receiving its own power of growth from things already grown; and again from the mineral kingdom, because it consists of parts derived from this kingdom. Hence it has its first beginnings from all these, and finally it enters the world organised from all these.

In these kingdoms the varieties are so great that chemistry and the physical sciences labour, as it were, under the accumulation of the phenomena. Were, however, any part wanting, the world would cease to be so perfect; for some part would be deficient in the order of connection; some link deficient in the chain. Hence the perfection of the world consists in its variety; and because variety cannot exist except by means of changes, it follows that the world is brought progressively to its perfection by means of various changes, contingents, modifications, series of things, and their several connections. We arrive, therefore, at the following conclusions. The greater the number of changes and contingents which concur in its formation; and the greater the number of modifications and existences of things successive, simultaneous and coexisting resulting therefrom, the more perfect the world. That perfection becomes more simple also in proportion to the extent of the series and the manifold con-

nection of the various series. For the more numerous the series of things, and the more various their connections, the more numerous are the things that exist and that are capable of modification; the more numerous are the causes and results of the variety; the greater too is the scope for the functions of mechanism and geometry, and for developing the motive forces of nature.

2. The world subsists by the same series by which it exists; and, in regard to its subsistence and existence, has perpetual relation to its primary. The more perfectly the world exists and subsists, the better can it regard its primary, consequently it is in its direct series more perfect and beautiful than in its indirect; in composite and connected things than in those that are simple and separate: in series having a larger and freer motion, than in those in which it is less so. Connection arises from parts that exist successively; for by these parts the connection subsists. If effects are to continue, so must causes: if causes are not continually associated with effects the latter cease. Effects themselves are, therefore, latent in causes, and thus also the world has its subsistence in its first principles; so also each end is perpetually associated with its intermediates; and in this way worlds endure from one age to another. The world has special reference to a beginning; both principles, the active and passive, are not only in continuous connection, but in perpetual vigour; provided all the entities in its series are in motion,—in the same, for instance, as that from which they originated. Thus does nature always live, as it were, and behold her origins connected together. In animals, as in elements, every series subsists only by motion; for we perceive the whole elementary particle with all its parts, and the parts of these again, even to the point, to be in a kind of perpetual motion; and in each elementary particle we see the whole process of its creation evident and manifest, resembling the world, both as it exists and subsists; that is to say, in every particle nature may contemplate her first end and her intermediate destinations.

3. The changes and contingents may be infinite, and also the varieties of modifications; and, therefore, infinite genera of entities may be simultaneously and successively formed, and afterwards brought into connection; consequently infinite series of these entities. Suppose the world had passed through a thousand changes before arriving at perfection—that it actually passed through many a thousand will be demonstrated in the sequel—now if, in one among these thousand changes, there existed even a single variety, the perfection of the world would at once be different from what it would otherwise have been, and other different series of things would arise. If then these thousand changes were successively multiplied into one another, according to the law of progressions, we should not even then arrive at the number of varieties produced, and this number would be so immense that volumes could not comprise it. Now we may also have an equally great number of series; for were there the least diversity in any intermediate change, it would immediately give rise to another collateral and perfectly different series of things successively and simultaneously existing. Nor are the changes and contingencies alone liable to these varieties, but also their modifications, and the entities thence successively or simultaneously arising, or the parts that constitute the world. It therefore follows, that if the world consists of a series of parts and compositions simultaneously and successively arising, there may be as many series as there are worlds, or as many worlds as there are series; and thus, that no world can be absolutely like another. For no changes, contingents, modifications, or entities, capable of modification, can be assigned as absolutely similar to one another.

4. Nevertheless, in every world-system, the principles of geometry are the same; and also nature and mechanism, as to first principles and motive forces; and the diversity consists only in the diversity of the series, in respect to degrees, ratios, and figures. For figure and space are attributes of every entity; and, therefore, geometry is associated with these entities throughout every world-system, and also nature and mechanism; for

its motive forces cannot be separated from geometry. There are, however, degrees, ratios, and figures, which vary according to contingents, vicissitudes, modifications, and their series ; and which, therefore, may be as numerous as these are.

Nature, consequently, cannot be modified in one world just as she is in another ; nor are the entities in one world capable of undergoing modification in the same way as those in another. Mechanism presents itself under different conditions ; because relations, times, and degrees are different ; all objects have a different configuration, and thus analysis exhausts all its analogies. In other worlds the air and ether, if there be anything similar to them, do not vibrate in the same way ; the organs of sight and hearing are also affected by them in a different manner ; nor perhaps are our organs capable of receiving the undulations of their elements, because they are not constituted in accordance with their mechanism nor adapted to the motions of their elements. The animals of this world might there, perhaps, be deprived of the use of their senses. Machines of every kind would there, perhaps, be constructed on different rules and by a different application of mechanical powers. The boastful Archimedes, who talked of moving the world out of its place by his mechanism, had he been translated to another system and earth, might perhaps have been less confident, when he found in those worlds all his skill and ingenuity disappear, and himself at a loss how to apply the common powers of mechanism. For, if he had wished to make any experiments there, he would have had to learn the very first principles and rudiments by means of the phenomena of that system. All the motions there tend to their equilibrium by other proportions and figures ; there other modes, contingents and causes, concur in the production of phenomena. For there no phenomena would be the same as ours ; they might be prodigies compared with ours. The learned men of our world, until they had become acquainted with causes there, might laugh at the philosophers of those worlds.

From these observations we may conclude, how great is the

extent of our ignorance. Every one measures his wisdom by his understanding of those things with which he is acquainted. The limit of his own information he considers to be the limit of all that is attainable; for he is ignorant of all else. The bounds of his knowledge are the bounds of his wisdom; and since he can advance no farther, he thinks it is impossible to go beyond this limit; and, therefore, he imagines that he is a very wise man. To the things of which he is ignorant he can place no limits. If, however, he could compare that which he knows with that which he does not know, how narrow and contracted would his knowledge appear; with eyes fixed upon the ground, how oblivious of himself would he be, and how mute with astonishment would he stand, while exploring the unknown immensity before him! And so at length he would smile at his own pride and that of the race! There is not a particle in our globe, with the thousandth part of whose nature we are acquainted. What do we know of the elementary kingdom, except a few effects? In the mineral, vegetable, and animal kingdoms, what we know is nothing compared to what we have yet to learn; for the soul knows nothing of those things which the senses do not perceive. What shall we say of other worlds, whose number is incomprehensible, especially when we reflect that the Infinite is capable of varying the primitive force in one simple form in infinite ways; consequently, geometry and mechanism also in infinite ways; that He can give birth to nature not only after the manner in which it is presented to our view in this world, but in ways infinitely diversified; that He, consequently, can call into being an infinite variety of earths and systems. It is, therefore, a mark of the highest wisdom to know that we merely know, and that our knowledge extends to, a very few things.

CHAPTER III.

RESUMPTION OF THE PHILOSOPHICAL ARGUMENT CONCERNING THE FOURTH FINITE, AND ITS ORIGIN FROM THE SECOND ELEMENTARY PARTICLE.

We here resume the subject of the finite, and deal with that which is fourth in order and one part in the series before the world arrives at its perfection. In elementaries there occur only the most perfect simples, namely, the passive and the active; from these, as from two principles, results a third or the elementary. Beside the finite, nothing active and elementary can exist throughout the whole of that kingdom: nothing, I mean, beside those two principles and a third formed of the two. Nature is thus most perfectly simple, and indeed more simple still; since all three may be reduced to one finite; in which both principles are latent, the passive as well as the active; for the finite may be passive as well as active; for, according to our principles, the cause of each is latent in this entity. Whatever, therefore, is said of the elements, is latent in each one of them; in the finite, the similarity in its part; and in its part, the similarity in its point; and the very quality of each principle is there latent: it follows that there is also latent the quality of producing things elementary, in an infinite variety of ways, by means of different series. And because the visible world is so diversified in all its kingdoms, and consists in a series of parts arising successively and simultaneously, the world cannot end in that in which it begins; or in any intermediate series; or in any primary or secondary part; for, in this case, there would be no series, and no ends, because no intermediates; consequently, there would be no world-system. Our first principles must, therefore, continue their chain of connection down

to the lowest and last things of our earth, or to the composites in which it has its subsistence.

With regard, therefore, to this fourth finite, we say that it is similar to the third ; that the third is similar to the second ; the second, to the first ; the first, to its simple or point ; and, consequently, that the fourth is similar to all the finites and to the point. Its motion is therefore similar ; it can be similarly passive, and constitute the surface of any particle : and can also be similarly active. Its attributes, essentials, and modes, are similar to those of the third finite ; it differs from it only in dimension, and, consequently, in degrees and momenta. Its origin also is like that of the preceding finite, for it arises from the second elementary particle in the same manner as the third from the first elementary particle. The cause and place of its origin are similar ; that is to say it is near the solar active space, where the second elementary particles were equally capable of being compressed into finites.

To dwell any longer on this part of the subject would be useless, as in our remarks on the third finite, part i., chap. viii., and in the other chapters iv., iii. and ii., we have anticipated all that can be said on the qualities of the fourth finite ; the only difference between the fourth and the others, being the difference between greater and less. We may thus see that it derives its origin from the second elementary particle, in the same manner as the third finite from the first elementary particle ; consequently, that they are of a different dimension ; that the fourth finite consists of individuals which are third finites ; and thus that the third finite is raised to a higher power. We now proceed to show that the whole solar and planetary chaos consisted originally of these fourth finites.

CHAPTER IV.

THE UNIVERSAL SOLAR AND PLANETARY NEBULAR MATTER, AND ITS SEPARATION INTO PLANETS AND SATELLITES.

As yet the vortex is void and empty; coursing round the sun like a torrent, and ever pursuing the same rotations. It encloses the sun in its centre, and never allows it to move out of its place or centre; on the other hand, the sun does not allow the element flowing round it to penetrate into its own space. It is this element which sets limits to the solar space; gives it a name, as it were, and enables it to be called space. Without this element, the actives would have no space, and then dispersing themselves far and wide into an illimitable void, they would pass beyond their proper boundaries. On the other hand, the sun communicates to its element a perpetual motion about itself; and imparts to it the name of a vortex and a world-system—a system which is merely one in the vast sphere, and which, as a part of the starry heavens, contributes to the formation of the whole. The sun, therefore, is now in possession of its vortex, and the vortex of its sun; both together constituting a system; for one cannot subsist without the other. Hitherto, however, the sun reigns, as it were, alone in a vast court. His empire stretches far and wide, but there are no inhabitants to serve and obey him, to whom he can issue his commands and give laws and enactments. Nor does the vortex possess anything which it can annually and continually carry round the sun, nothing to which it can impart its functions. Phœbus remains in her abode bright and sublime. No hours, days, or years, as yet surround his throne. As yet there is no charioteer; he has no chariot into which he may mount; there is no quarter to which he may direct his steeds; there is neither rising nor setting, neither east nor west; because

as yet there is no earth to originate the distinctions of morning and evening; much less is there anything for the genial rays of the sun to warm, cherish, vegetate, animate, and vivify. But because the simple must precede the existence of the compound, the vortex, which is most simple, with its space, must exist before the earth, proceeding from a series of successively and simultaneously originating things, is able to exist in the vortex; for the vortex cannot as yet carry within it any composite, since the composite itself has yet to be compounded; it cannot waft any earth or planets along its current; because these are not yet come into being, but have to be brought forth by changes, contingents, and modes of indefinite kinds. As yet the planets are only in a state of conception; the ovum alone is produced, out of which they have to be sent forth.

Now reason asserts that causes must exist before effects; the simple before the compound; principles before principiates; that is to say, actives, passives, and elementaries, before a series of things arising successively and simultaneously. The first must exist before the intermediate; the intermediate before the ultimate. Reason, therefore, asserts that the planets must derive their origin from causes in time and in place; that causes are latent in first principles; in short, that the earths in our system must have originated successively. Now if, according to reason, the planets are effects from causes in time and in place, it remains for us to state what those causes are; what the time, and what the place. As to causes we may observe that they are those which are latent in the first principles; that is to say, in the active, the passive, and the elementary which is compounded of both. As to time, the planets could not have existed before the causes which produced them; that is, before the actives, passives, and elementaries. As to place, that could be nowhere else but where their causes concurred to produce them; and this could be only about the active solar space, where everything was present which could produce and give birth to such effects. And, because causes always accompany the effects, it follows that effects can be produced only in the place where the causes

are. All things were in proximity to the sun; and therefore, that the planets had their origin near the sun, must be shown in the present chapter. This may in some measure be deduced a priori; as for instance, that the sun is the first moving power in its universe; that it is the parent of its own vortex; that everything in the vortex owed its origin and subsistence to the sun; and, consequently, that all the parts in the vortex belong to it. Now nature, in her prepared state, can be productive only where she abounds in first principles. She cannot be in preparation or effort to produce in the midst of the vortex, or here give birth to her progeny; for the causes of conception and production do not lie at such varied distances from the sun; nor are they to be found among merely elementary particles.

To this conclusion reason herself may come by the aid of her powers of analysis. Therefore the ancient philosophers, from the use of reason alone, maintained that there was a kind of universal condition both of the sun and planets, in which there was simultaneously everything which could conduce to the perfection of the world-system. That is to say that both Tartarus and the sun, day and night, soft bodies and hard, were latent, in a word, all the seeds and elements of the things that were subsequently produced. And if this universal condition were in the vortex, it follows that it could be only near the sun. Let us first consider these opinions of the ancient philosophers, before we proceed to the immediate subject of our chapter. All, with the exception of Aristotle,[1] seem to have favoured the conjecture, that, primevally, there was only an unformed, composite, confused mass, in which there was as yet no differentiation; that from this mass all things afterwards went forth as an infant from the womb. From this conception they afterwards deduced the origin of things. They supposed that there was a state of conflict among these elements, not unlike that in fermentation, for they knew that nature by a kind of combat and collision tended to a state of equilibrium. On

[1] Aristotle's system of Nature is contained in his *Naturalis Auscultatio* and *De Cœlo.*—*Trs.*

the cessation of discord, heavy bodies passed to their place, and light bodies to theirs; bodies without motion and bodies with motion sought respectively their proper position; and thus from reason guided only by a very few phenomena, they concluded that when the strife of nature was over, an harmonious world-system arose out of chaos. These philosophers, therefore, were shrewd enough to guess the preëxistence of a chaotic condition; although they were ignorant of the series by which the various things were brought into existence. The philosopher naturally embraces the opinion which seems to him to be the most agreeable to reason, the most resembling visible nature, and which presents the least difficulties; for he is anxious, of course, that in future ages his system should not fall to pieces, in consequence of inherent contrarieties. The mind, therefore, naturally chooses the least difficult path, which it pursues like a traveller in the dark, who gropes his way in the direction in which he meets with fewest obstacles; and so follows the path, although he does not see it; he touches the various objects that come in his way, although he knows nothing of what he is touching, and arrives at the end of his journey, though he cannot tell how. In the same way the ancient philosophers were led to surmise the existence of a chaotic state common to the sun and the planets; although in what manner it existed, of what kind it was, and by what means it came to be such, they were entirely ignorant. This at least we may assume from ancient philosophy—a conclusion highly agreeable to reason—that primevally there was a universal chaotic condition both of the sun and planets; on the other hand, any other hypothesis is less conformable to the facts. Epicurus maintained [1] that the whole universe arose from a chaotic state; not only the earth, but the planets, the sun, and all the stars; that is to say, the whole world-system. Hence Aristophanes observes:

> "Chaos and night
> Black Erebus, and squalid Tartarus,
> Were first of all; earth, air, nor heaven was yet.

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[1] *Fragmenta de Natura*, lib. xi.—*Trs.*

But in unmeasured gulfs of Erebus
The black-winged Night first lays a windy egg,
Whence in the circling hours sprang wished-for Love,
The golden feathers glitt'ring on his back,
Resembling the tempestuous vortices ;
He through the wild domain of Tartarus
Mingled with chaos' darkly winged form,
Begot our race and brought us forth to light.
Th' immortal kind, ere Love confounded all things,
Had no existence yet ; but soon as they
Were mingled, heaven with ocean rose, and earth
And all the gods' imperishable race."[1]

Ovid, also borrowing his ideas from the ancient philosophers and Greek poets, thus beautifully and eloquently writes in his Metamorphoses :—

"Ere Earth and Ocean and all-covering Heaven
Grew into separate form, great Nature's face
Through all existence but one aspect wore :—
Chaos 'twas called ;—a rude unfeatured mass,—
A mere vast weight inert,—discordant seeds
Of ill-matched things in one huge heap compressed.
No Titan gladdened yet with light the world ;—
No Phœbe filled anew her growing horns ;—
No floating Earth in Æther circumfused
By her own weight hung balanced ;—round the shores
No Amphitrite twined her circling arms.
Land, Water, Air, together mixed and blent ;—
Land stable to no foot,—Water which gave
No space to swim,—and Air devoid of light.
No proper form to aught :—perpetual jar
And conflict, through the mass, of Hot to Cold
Opposed, of Wet to Dry, of Soft to Hard,
Of Light to Heavy,—till the Power divine
And kindlier Nature bade their contest cease,
Dividing Earth from Heaven, and Sea from Earth,
And liquid Æther from our grosser Air :
Which, from the blind heap where they lay, evolved,
And each to separate place assigned, she linked
Thenceforward in the holy bond of Peace.
Then first the weightless force of convex Heaven
Shot upward, like a fire, and took by right
The topmost station :—next beneath, the Air,
Second in lightness and in place. More dense
Than these, our Earth the grosser elements

[1] *Comœdiæ*, "Aves," ll. 693-702, translated by C. A. Wheelwright.—*Trs.*

Together drew, by her own weight depressed
To lower seat:—while Water, outmost, seized
The wardship of her borders new declared,
Circumfluent, belting the compacted World.
When thus whoever of the Gods it was
Disposed the severed mass, and severing ranged
Its elements,—first, lest our Earth should lie
From end to end one flat and level tract,
Into the fashion of a mighty globe
He orbed her form," etc.[1]

It was the general opinion of ancient philosophers that Night and Tartarus originated from chaos; that from Night sprang the Earth, the Ocean, the Heaven or the Ether, and also Love; so that Night and Tartarus were first-born and twins; that from these arose everything else of which the world consists. The ancients held also that, from the same chaos, the gods and goddesses derived their origin; hence they believed that their origin was not from eternity, but in time, and cöeval with that of the earth; especially as some god or other presided over each element, and, indeed, over everything of which they had any general conception. The God who separated the various things out of the chaotic mass they denominated Love. Ovid, however, says that he was ignorant which of the gods it was that performed this office; for he observes:

"The Power divine
Or kindlier Nature bade their contest cease" (l. 21).

And again:

"When thus whoever of the Gods it was
Disposed the severed mass, and severing ranged
Its elements,—first, lest our Earth should lie
From end to end one flat and level tract,
Into the fashion of a mighty globe
He orbed her form" (ll. 32-33).

Aristophanes likewise observes:

"Th' immortal kind, ere Love confounded all things,
Had no existence yet; but soon as they

[1] *Metamorphoses*, lib. i., ll. 5-33, translated by H. King.—*Trs.*

Were mingled, heaven with ocean rose, and earth
And all the gods' imperishable race." [1]

The Mosaic philosophy in some measure coincides with the ancient philosophy of the Egyptians, and with this of the Greeks and Romans; for Moses also believed that there was a chaos, since he relates that "The earth was unformed and void, and darkness was on the face of the abyss; [2] [and the Spirit of God moved upon the face of the waters;]" he makes mention, therefore, of a chaos, darkness, an abyss, and also of a Spirit. Some have, consequently, held the opinion, that the chaos of Moses was the same as the chaos of the ancients; that the darkness he mentions was the same as their night, which arose from chaos; that his abyss was the same as the Tartarus or ocean of the ancients; that the "Spirit upon the waters" was the same as the Intelligence and Love of their theory. Moses, having narrated the origin of the earth from chaos, begins with light; and afterwards places the greater and lesser luminaries in the heavens, such as the sun, moon, and stars. Having stated these facts, he says that, "The heavens and the earth were finished, with the whole host of them." [3] He also refers to certain gods and sons of gods who disported with the daughters of men; and also to other details, to which we find resemblances in ancient philosophy. It is said in the eighth chapter of Proverbs that God set the world (or sphere) on the face of the abyss; [4] and many other things which authors have shown who have written on chaos.

Let us, however, now observe how reason and our chain of argument lead us to the conclusion we need, that originally there was a universal chaotic condition, common to the sun and planets; in which the origins of all things were latent; and which, by various changes, contingents, and infinite modes, ultimately produced a long and multiplex series; that is to say, series which filled and adorned this globe of land and water with elements and minerals of the most diversified natures,

[1] *Comœdiæ*, "Aves," ll. 700-702, as above.—*Trs.*

[2] Genesis i. 2. [3] Genesis ii. 1. [4] Proverbs viii. 27.—*Trs.*

and also with trees and living things. Let us consider here the origin of the earth; how it was conceived; how it lay; how, in this state, it was cherished, then sent forth, and thus introduced into a state of infantile existence; how it gradually advanced to adolescence, and finally arrived at a state of old age.

1. The second elementary particles by reason of the same causes, are most highly compressed near the solar active space; and, in consequence of this compression, they cease to be elementaries. Finites exist in the same manner as first elementaries; but these finites exist from second elementaries of a higher dimension, and are the fourth in order, the former being third in order. It follows then, that the second elementaries are very similar to the first; that they are in the same volume with them, in the same revolution round the sun, in one and the same common state, and thus that each kind may fulfil the same destiny. It results also from the theory of each element and of the third and fourth finite, that, in the state of the formation of the vortex, or before the elementaries can become circumfluent, they dispose themselves into a general and synchronous motion, adapt either themselves to motion or motion to their figure, and are fluent in a state of equilibrium; that they can in this state, be compressed, and when compressed, may recede into themselves, and lose their elasticity and their capability of compression, that is to say, all their elementary character; that they may lose, in a word, one first principle of their nature, which is the active; thus that they cease to be elementaries, and exist as fourth finites near the sun.[1]

2. Although all finites possess this power of self-activity, nevertheless, those which have their origin near the sun are not capable of becoming actives, of entering into the solar space to its actives, in consequence of a difference as to velocity, circles, and mass; but the actives which may have been casually made, cease to be actives, and necessarily remain mere passives

[1] See Chap. VI., art. 21, 22, 26; Chap. VIII., art. 4; Chap. IX., art. 10; Chap. X., art. 3; also Part III., Chap. III.

round the solar space of the actives; consequently, the functions they there perform are those of a guard, to prevent the other finites of the same kind from penetrating into the solar space, and thus from any longer projecting themselves into it. We have frequently stated in the former parts of this work, that all finites may become actives, if they have free space allowed them; and in chap. ix. of the present part we shall explain how all these finites may become actives, like others of the same kind. In part i., chap. vii., sec. 2, on the actives of the third finite, art. 6, 7, 8, we may see that the actives of a higher power and dimension cannot be in the same space with the actives of the first and second, because of the difference in velocity, circles, and mass, but must, by means of the influx of the smaller actives, namely, the first and second, be immediately deprived of all their active force. These finites, therefore, deprived of all power of actuating themselves, occupy their place round the sun as mere passives; and, arranged round this space, they enclose it on every side; but if they enclose they protect it, and prevent other finites of the same kind, which are present, from rushing in; for they act as a barrier between this space and the volume of similar finites; that is to say, they are intermediates between this space and the other finites.

3. In this manner the number and quantity of finites of the fourth kind increase more and more, by reason of the successive compression of the elementaries; and they also become compact round the solar space. The finites thus formed an immense volume, and crowded around and enclosed the sun in such a manner as to form an incrustation; nor did they cease to act till the vortex was fully formed. These effects arose from the same cause as the former. For if in the process of the formation of the vortex the elementaries were compressed, and in consequence of their great compression ceased to be elementaries, divested themselves of their elasticity and capability of yielding, and were deprived of their active principle, their number would continue to increase until the vortex was completely formed; according to the theory propounded in part i., chap. x. In

this manner the finites would be drawn hither in crowds, and press closely upon the active space, and, like an extremely dense crust or cloud, they would interpose themselves between the vortex which had to be formed and the solar space. So also they would intercept the immediate force of the space, and its operation upon their vortex ; they would destroy all contiguity ; and, consequently, would throw into shadow the whole of the world-system, darkening it as if by an extremely opaque cloud, and superinducing upon it another and different state. They would also thus give rise to another remarkable change, by means of which would arise new accidents, and, as it were, new causes, which would conduce to the further perfection of the world. In the sequel it will be shown that the sun, surrounded with this crust and enclosed in the middle of it, was thus, as it were, in a pregnant state, and ready to introduce something new into the vortex ; and that it is in this manner, that not only the sun, but also all its planets, were once in a chaotic state ; in which the beginnings of all that was afterwards produced were latent.

4. Nevertheless this crust, formed around the sun, and consisting of fourth finites, is carried round by a kind of revolution. It is thus representative, as it were, of an active centre in forming and perfecting the vortex, around which, consequently, the elementaries could nevertheless flow in a vortical current, but with a potency and force different from that which they would possess in case the solar space acted nakedly and contiguously upon the circumfluent elementaries. That this collection and incrusting aggregation, consisting of fourth finites and surrounding the sun, had nevertheless a circular motion, is evident from this, that it was formed in this very motion itself. When the elementary particles cease to be elementary, the cessation is in consequence of the motion of the particles in contiguity, and is thus effected in motion. In every degree of compression, therefore, they retain and preserve the impressed force. By the compression of the elementaries upon the finites, the state induced upon them was that which existed during the state of compression ; the actives within constantly acting in the space,

and an immense volume of elementaries without being put into a vortical motion, just the same as we see in our own visible world. If, for instance, a volume of water is carried round a centre or axis, we find that when the moving force ceases, the motion at first impressed still continues; until, in consequence of the mutual contact and resistance of the parts, a state of quiescence commences. So also in the crust which surrounded the sun, the pristine state of motion was for a considerable period preserved, and was changed only in consequence of an increase in its quantity, and after a certain interval; it would, moreover, be rendered less yielding, by the condensation and increase of the parts, and also by lapse of time. For the parts tend to a state of equilibrium; and because they are not elementary, they in course of time gradually tended to a state of rest. In the meanwhile, as the crust continued its motion round the sun, it was not unlike the effluvium circulating round a magnet, which, by means of its motion round an axis, constitutes an active centre; so that the elementary particles could move around it as a centre, and the vortex itself be advanced to another stage of formation. On this subject the reader is referred to the whole of part ii. of our *Principia.*

The following is the substance of all that we have to state here on the subject of the figure and motion, or geometry and mechanism, of the solar crust. The whole of this immense crust, together with the enclosed solar space, is not unlike an elementary particle; for in each elementary particle there is an active space, exteriorly to which flow the finites. Thus, both as to figure and motion, this chaos is, on an immense scale, an effigy of each individual part of an elementary particle. Thus nature is similar to herself in her largest as well as her least productions; and thus she appears in her most stupendous proportions, as well as in her most minute. In the present case, therefore, we may apply many of the remarks which we have formerly made on the subject of elementaries in chapters vi. and ix., part i.

5. This incrusting matter, being endowed with a continual

circular motion round the sun, in the course of time removed itself farther and farther from the active space; and, in so removing itself, occupied a larger space, and consequently became gradually attenuated, till it could no longer cohere throughout, but burst in some part or other. That this crust, covering the sun and rotating round it, was removed gradually to a greater distance from it, is evident from this fact; that the space within was continually active, and incessantly acted upon the walls and barriers of its prison; that the incrusting expanse or volume which was perpetually revolving, tended, by its centrifugal force, to a farther distance, like all other bodies having in any medium a circular motion, the rules and principles of which are sufficiently well known to the learned. It is evident, also, that the heavy bodies in the solar vortex tended from the centre to the circumferences; on which subject we shall speak more at large in the sequel. The effort and tendency of this crust toward the peripheries and beyond them, arose, therefore, from a threefold cause. Now if the tendency of the crust is to fly off to a greater distance, it follows that it must become gradually attenuated, because the same volume occupies a larger circle. That the expanded matter became attenuated by the increase of the circle in magnitude, is a purely geometrical fact; as also, that if it became attenuated and was in perpetual motion, it in some part or other was broken up. It is needless, therefore, to dwell any longer on what is already demonstrated, and of the truth of which there cannot be a doubt. We shall only add, that this expanded matter, being on a larger scale similar to the most minute elementary particle, would, by too great an expansion, be broken up, on the principle we have already mentioned in regard to elementary particles, part i., chap. vi., art. 27.

6. The solar crust, being somewhere broken up on the admission of the vortical volume, collapsed upon itself; and this toward the zodiacal circle of the vortex, or conformably to the arrangement and motion of the elementary particles; so that it surrounded the sun like a belt or broad circle. This belt, which was formed

by the collapse of the incrusting expanse, revolved in a similar manner ; removed itself to a greater distance ; and by its removal became attenuated till it burst, and formed into larger and smaller globes ; that is to say, formed planets and satellites of various dimensions, but of a spherical form. That the crust, when it had been broken and had collapsed upon itself, was arranged round the sun in the form of a belt, and in accordance with the equinoctial plane of its vortex, which is the same as the plane of our zodiac, is evident from the mechanism of the elementary particles, which, by reason of their arrangement and motion form a vortex or gyration proceeding from the centre toward the equators of the parts ; conformably to the direction of the spiral motion. This appears to be more particularly the case when we consider that the element can now act on all sides and arrange the moving parts into conformity with the situation and motion of its particles ; a fact which we may see illustrated by innumerable phenomena occurring in liquids. From our preceding theory it is evident that the belt thus formed had also a rotatory motion, and became ruptured by its removal to a further distance from the sun. That it formed itself into globes, may be inferred from the equal pressure of the element in all directions. See chap. vi., art. 46-49, part i. It is in consequence of equal circumpressure, that liquid bodies take the form of globes, as water does in air ; quicksilver in water, air, and ether : indeed all bodies, dissolved and liquefied by heat, and equally pressed by any element on all sides, form themselves into spheres.

7. This incrusting expanded matter might subside partly into itself, and thus consist merely of a volume of finites. It might partly subside inwardly, or toward the solar space, and thus revolve round some active space. It might partly subside exteriorly or toward the vortex, and thus enclose a volume of elementary particles. Thus there might exist bodies of three different kinds, namely, planets, satellites, and erratic bodies straying round the sun, such as we are accustomed to call solar spots. Of this subject, however, we shall derive a better conception from the figures about to be presented.

It therefore follows, that these bodies, separated into globes, consisted of fourth finites; that they directed their course into the vortical current according to their size and weight; that

Fig. 98.

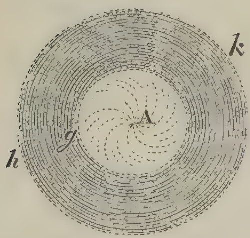
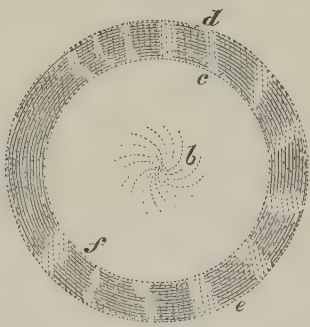
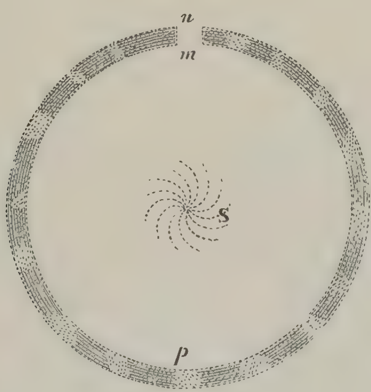


Fig. 99.



they continued more and more to increase their distance from the sun, until they arrived at their destined periphery or orbit in the solar vortex, where they are in equilibrium with the volume

Fig. 100.



of the vortex. On this subject see the sequel, chap. x. and xi. Let us now illustrate by sketches the nature of the incrusting expanded matter and belt; for a thousand words will not convey the idea which may be derived from a single representation; and besides, the understanding may form a more distinct idea

Fig. 101.

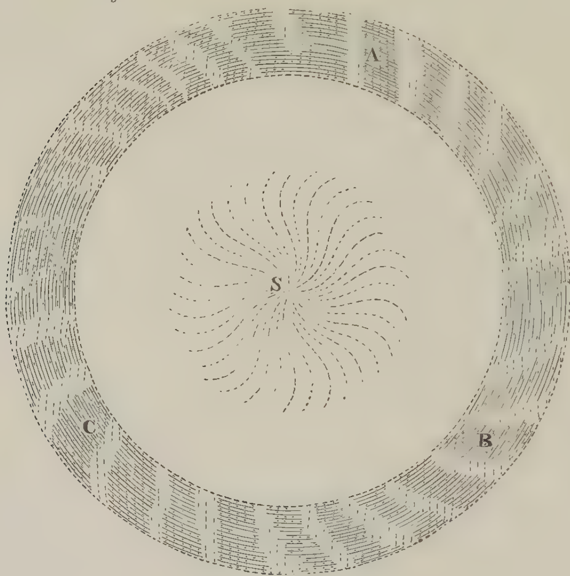
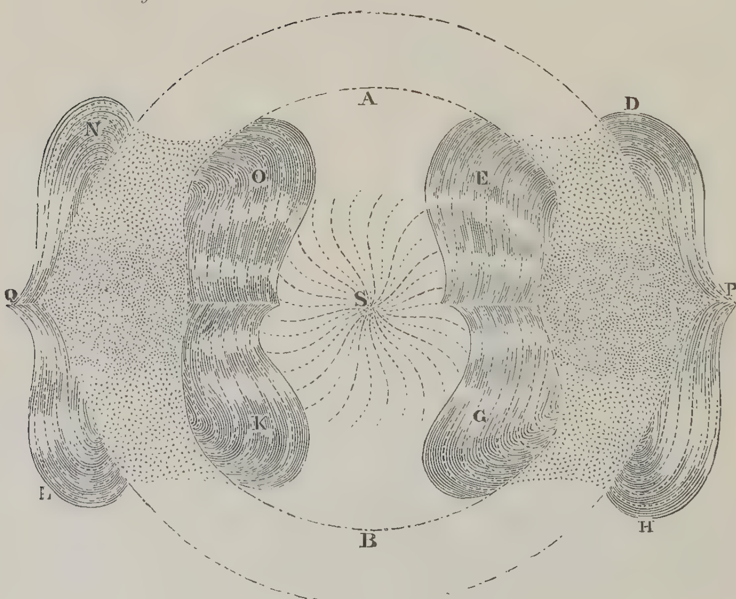


Fig. 102.



of an object the clearer and more distinct the impression made by it upon the organs of the senses. We shall now give sketches of this solar crust, and its state of separation. In fig. 98, A is the solar space; *kh* the crust consisting of fourth finites, which revolved round the sun. Fig. 99 shows the same crust expanded into a larger ring, namely, *c*, *d*, *e*, *f*, whose volume equals the volume in fig. 98. The whole internal space is occupied by the actives of the sun. Fig. 100 shows the same crust still larger and more expanded, broken at *mm*. This opening affords a passage to the vortical element to rush in, and enable it to act upon all sides, as we shall more clearly perceive in the following figures.

Fig. 101 shows the crust having a still greater density, and about to undergo a disruption. Fig. 102 shows the state of disruption or collapse. One part takes an inward direction, as EG and OK, carrying away with it also a part of the actives of the sun, and surrounding them with itself. Another part takes an outward direction, such as DPH and NQL, occupying the volume of the element flowing without, and enclosing it by agglomerating around it; intermediately, however, it subsides as it were into itself. A and B are the quarters where the poles are; the subsidence takes place in all directions toward the equator of the crust or the vortex, and conformably to the situation and motion of the parts in the vortex. Fig. 103 shows the crust that has collapsed into the form of a belt in the plane of the equinox, about which the bodies A, I, K, L, M, N, O, P, are situated, in which is enclosed and concentrated the vortical element. Interiorly, however, as at Q, Q, Q, Q, Q, are the bodies in which are enclosed and concentrated the actives of the sun. The belt itself consists entirely of fourth finites. Fig. 104 shows the formation of the bodies into globes, after the disruption of the belt. To these still adhere partly the lighter bodies, such as *g*, *h*, *k*, D; in which the light vortical element lies enclosed. All the bodies are thus in the plane of the equator, or as appears to the inhabitants of this earth, in the plane of the zodiac.

Fig. 103.

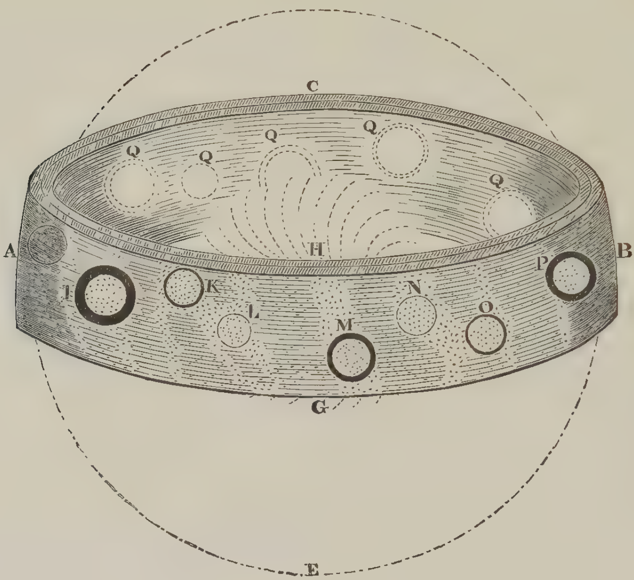


Fig. 104.

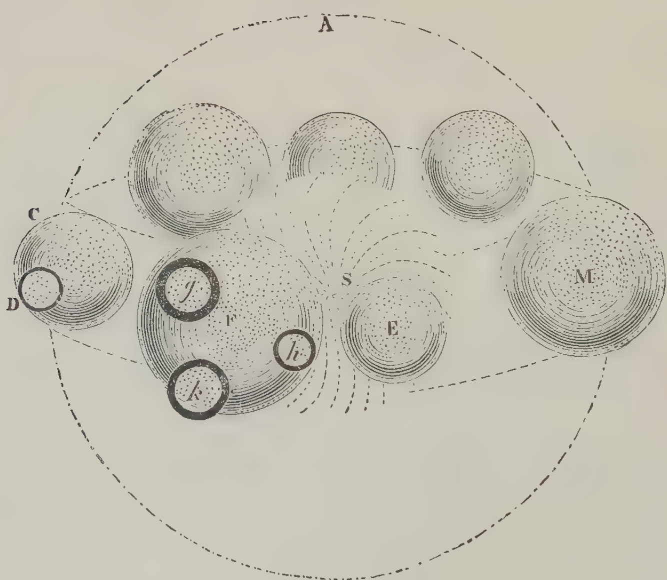
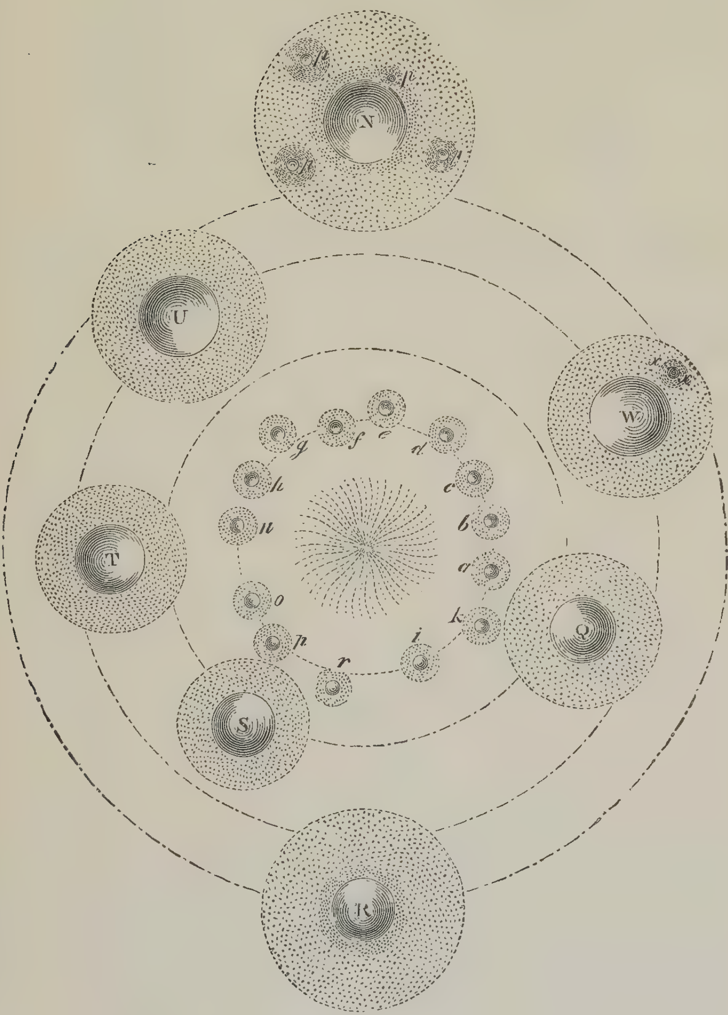


Fig. 105 shows the same bodies issuing from the sun, and going toward the circle of their orbit, as R, Q, W, N, U, T, S;

Fig. 105.

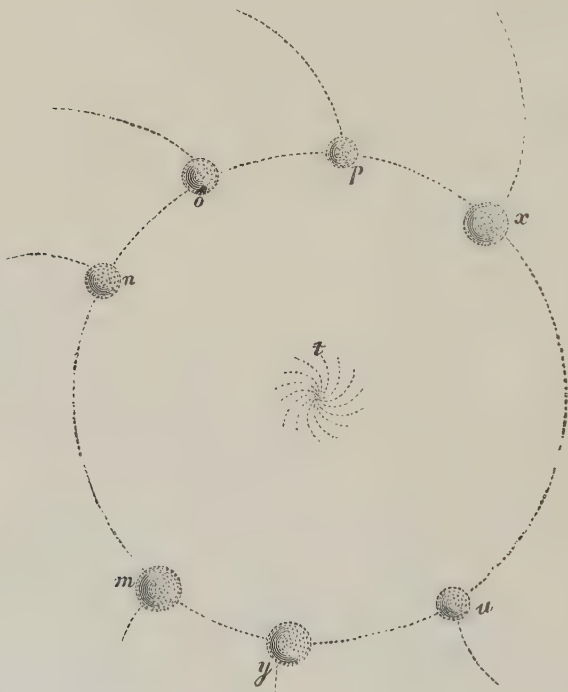


the lighter bodies accompanying them, such as p, p, p, x; all of which become gradually surrounded by the other in the course of their journey. In fig. 106 we see the journey of these bodies

from the sun, together with the lighter bodies denominated spots of the sun.

Now if the entire chaos existed in this manner, it follows that for a considerable period the sun would be shut out of its vortex; and lie with its beams imprisoned within a crust,

Fig. 106.



without any elementary expanse into which it could diffuse itself. Ovid accordingly says that it's "face was in pitchy darkness veiled;"[1] and in another place, that "Such double night of storm and pitchy cloud obscures the guiding skies;"[2] also, when he sings of chaos, that "No Titan gladdened yet with light the world,"[3] and "The air was void of light;"[4] and again, in the sequel, that now, "The weightless force of convex

[1] *Metamorphoses*, lib. i., l. 265, translated by H. King.—*Trs.*
[2] *Ibid.*, lib. xi., ll. 549, 550. [3] *Ibid.*, lib. i., l. 10.
[4] *Ibid.*, lib. i., l. 17.—*Trs.*

Heaven shot upward."[1] In this way did the ancient philosophers conceive that Night and Tartarus were in a chaotic state; and that from Night sprang the Earth, the Ocean, and the Heavens. Moses also makes mention of darkness, and of an abyss. But Aristophanes and others come still nearer to our philosophy:

> "The black-winged Night first lays a windy egg,
> Whence in the circling hours sprang wished-for LOVE,
> The golden feathers glitt'ring on his back,
> Resembling the tempestuous vortices."[2]

This is the same as if he had thought that the sun was enclosed in an egg, from which, endued with revolving motion, it afterwards went forth.

This philosophy is not without evidence derived from actual observation, for celestial phenomena appear to confirm it. Stars have been known to come into view, and after a lapse of time, to grow obscure and become invisible: then again to become visible, and again obscure; so that either they disappear altogether, or else, unless some neighbouring stars should in the meantime occupy their vortex, remain permanently in sight. Here then we see the origin of the planets actually imaged forth to the eye. We see, as it were, the same incrustations arising from the compression of the circumfluent elementary parts, and veiling over the star or sun to which they belong; we see also their repeated dissipations and separations. Astronomy is full of evidence of phenomena of this kind, and continues to this very day to offer to the eye those representations of chaotic condition of which we have been speaking; forbidding, as it were, a single doubt upon the subject. I shall here adduce the remarks of one astronomer only; the celebrated David Gregory, who, in his *Astronomiæ Physicæ et Geometricæ Elementa.* Oxoniæ, 1702, lib. ii. (prop. xxx., pp. 171, 172), says:—

"In the age of Hipparchus, according to the testimony of Pliny,[3]

[1] Metamorphoses, lib. i., l. 26.—*Trs.*
[2] *Comœdiæ*, "Aves," ll. 695-697, translated by C. A. Wheelwright.—*Trs.*
[3] *Naturalis Historia*, lib. ii. cap. 24.—*Trs.*

there appeared among the fixed stars a new one, between which and the celebrated star in Cassiopea, which appeared in the year 1572, Riccioli [1] enumerates the appearance of six other stars. The new star in Cassiopea, which seemed to be of the first magnitude, appeared about the beginning of November, in the year 1572; and continued till the month of March, in the year 1574. This star, as well as the one which appeared in the age of Hipparchus, gave occasion to Tycho Brahe to make observations on the fixed stars; as he himself states in his *Astronomiæ Instauratæ Progymnasmata*, Pragæ, 1610, p. 319, in which he expressly treats of this new star.

"In the month of August, A.D. 1596, David Fabricius observed a new star of the third magnitude in the Whale, which disappeared after two months.

"In the year 1600, a new star appeared in the breast of the Swan; formerly seen by others, and afterwards by Keppler himself, who gave an astronomical account of it. This star, according to Hevelius (who observed it with larger instruments from the year 1638), maintained the same magnitude, namely, the third, until 1659; but decreased noticeably from the year 1659, and, when the year 1661 ended, entirely vanished. After an interval of five years, or in the month of September 1666, it reappeared so as to be visible even to the naked eye, and was seen by Hevelius as a star of the sixth or seventh magnitude, in exactly the same situation it had previously occupied.

"In the year 1604, about the beginning of October, a new star was seen in the right foot of the Dragon, which appeared larger than Jupiter and nearly equal to Venus. This star lasted for a whole year; but after the month of October 1605, became invisible. Keppler published a pamphlet upon the subject.[2] These three new stars, viz., the one in Cassiopea, the one in the Swan, and the one in the Dragon, were seen in the galaxy; which consequently came to be denominated by some the

[1] *Almagestum Novum.—Trs.*

[2] *De Stella Nova in Pede Serpentarii.* Pragæ, 1606.—*Trs.*

treasury of new stars. Other new stars also have been observed; one, for instance, in the year 1612: this was seen in the girdle of Andromeda, by Simon Marius, author of the *Mundus Jovialis*: another in Antinous, by Jobst Byrg, clock-maker to the Prince of Hesse; as also by others.

"In the year 1638, Joannes Phocylides Holwarda,[1] of Franeker, observed a new star of the third magnitude, or still larger, in the neck of the Whale. The manner in which this star vanished and reappeared every year, but not always at the same time, (though Boulliau thought it was,[2]) and how after four years it became again finally invisible, may be learnt from the history of it given by Hevelius, and annexed to his account of the planet Mercury,[3] as also from his *Annus Climactericus*, Gedani, 1685. Massini found by observation, that the phases of this star recurred after nearly 330 days; for sometimes there was a difference of 17 days in the commencement of the phase, either sooner or later. This star seems to be the same as the one which Fabricius had observed in the year 1612; for the localities of the two coincide.

"In the month of July, 1670, Hevelius detected a new star of the third magnitude under the head of the Swan; and which, in his *Catalogus Stellarum Fixarum*, Gedani, 1687, he assigns to the Little Fox. After a short time it began to decrease, and about the end of August, 1671, entirely disappeared; but, in the month of March following, it again came into view, at first like an extremely minute star, from which it gradually enlarged to one of the third magnitude. After this it again diminished; so that in the month of September, 1672, it became wholly extinguished, and was never afterwards seen.

"Besides these, there have been seen other stars of various magnitudes, as of the 4th, 5th, and 6th, which were known to the ancients, and were observed also by Tycho Brahe; but which also have, in turn, gradually become extinct, as we may

[1] *Epitome Astronomiæ Reformatæ Generalis.* Franekeræ, 1642.—*Trs.*

[2] *Astronomia Philelaica.* Parisiis, 1645.—*Trs.*

[3] *Historiola Miræ Stellæ*, appended to *Mercurius in Sole visus Gedani, anno* 1661. Gedani, 1662.—*Trs.*

find on examining Hevelius' *Catalogus.* Hevelius mentions four in his *Prodromus Astronomicæ*, Gedani, 1690; one star, namely, in the left thigh of Aquarius, preceding the adjacent one in the tail of Capricornus; a second in the belly of the Whale; and another, the first of the shapeless ones behind the beam of the Scales. Other observations upon these stars have been made by French astronomers. Besides all this, the large fixed stars of the first, second, and third magnitude are found to experience considerable changes, in regard both to lustre and dimension; as is evident from the different accounts given us by various astronomers concerning fixed stars of the first and second, or second and third magnitudes. And in order that posterity might be the more easily able, and without error, to judge of the changes experienced by the large fixed stars, Hevelius in his *Prodromus* has recorded a variety of observations made by himself."

From these statements it is evident, not only that stars are seen to come into view in the heavens, but that afterwards they form around themselves another element, and in course of time become incrusted; that, in this state of incrustation, being situated among so many neighbouring stars that are arranged in their own sphere in regular order, they are unable to bring any vortex around themselves to perfection, and consequently always remain in a state of suspended formation; that, therefore, they become incrusted, continue in their state of incrustation, and thus remain concealed from our view.

CHAPTER V.

THE ETHER OR THIRD ELEMENT OF THE WORLD.

HERE we again revert to first principles, being obliged to have recourse to repetition, because these principles are always the same and are only two in number, namely, the active and the passive ; one of which also is only the cause of the other. Nature constantly retains the greatest similarity to herself, and, as we have stated above, presents herself to us the same in her largest as in her least forms. She is the same in the solar system as in a minute volume ; the same at her birth as in her adolescence ; the same in the simple as in the compound ; the same in one end as in the other, and, therefore, also the same as in intermediates. If even she extended her heaven infinitely beyond its present limits, she would still continue one and the same, were it the will of the Deity that her primitive force should continue to be the same : that is to say, if nature is the same as she is in our world. Nature, therefore, is similar in the undifferentiated state and in her vast aggregation of actives and finites, and in her elementary particle or minutest aggregation of actives and finites. And although this huge particle or mass be differentiated and divided into parts, that is to say, into globes or planets, still nature remains similar to herself ; that is to say, similar to herself in the large individual entity or planet and in the small or finite entity. Every planet therefore, however great, is nevertheless such as the finite is ; or it is merely a large finite ; the difference between the two consisting only in degrees and dimensions. A large entity is similar to a small one, nor can nature be in the former different from what she is in herself. A planetary globe consists of fourth finites, which are its individual parts, and which are always the same

whether in a larger or smaller volume or mass. For every individual part possesses the same force by derivation from the primitive force in the point, and these individual parts cannot actuate themselves, or finite themselves in a smaller form, so long as they remain so closely conjoined, except at the surface. These parts, therefore, or fourth finites, operate in the large body or system in the same manner as they do in the smaller. If, therefore, a planet derives its similitude from its own finite, or its individual parts, it does so more especially in regard to its tendency to a similar motion, or a similar intrinsic and progressive motion, and a similar axillary motion. These are the essentials of every finite in its least boundaries as well as in its greatest. That every planet possesses a progressive motion, we shall show in our theory of the earth, when we come to treat of its polar vibration and the progression of the nodes in the ecliptic, which is slower in proportion as the finite is larger or more spacious; for all the corpuscles in so large a body, supposing them to preserve the form of their arrangement, cannot but consume ages in performing their progressive motion.

Astronomers know perfectly well that a planet possesses an axillary motion; the fact is doubted only by pseudo-astronomers. Indeed the phenomenon may be observed by anyone who views the planets through the telescope. Its existence in the case of our own earth, is evident from the apparent motion of the sun; We have, therefore, in this our large planetary finite, from a similar cause, an axillary motion in conformity to the plane of the equator. With regard to the local motion of the planet, there can be no doubt of it, for it performs an annual revolution round the sun; a motion which returns into itself by aid of the vortical element, in which it is contained, and which pursues a similar direction; so that in the production of the motion of the earth, there is a twofold cause. What, therefore, we have said of the finites, of the progressive motion of their parts, of the axillary and local motion of the whole, is applicable to our own earth. And all that is said upon the subject in part i. might here be repeated and applied to the motion of each planet,

were it not desirable to avoid repetition. The reader there is referred to the theory in part i., chap. ii., iii., iv., and viii.; and to chap. iii. in the present part. We may also here apply what we have already said of actives; for planets which are rendered active by their local motion round the sun, have the same motion as actives. On this subject the reader is referred to part i., chap. v. and vii.; also to chap. viii. in the present part.

When the sun, which has been so long pregnant, has at length given birth to its numerous offspring, then the whole family of planets surround him as a parent, disporting about him in virtue of their inherent and inborn motions; and having arrived at the age of adolescence, they take their leave, in order to pursue their journey throughout his extensive empire. Thus each one in turn abandons his procreator, and seeks the province destined for his own proper habitation. The sons of the great common father divide the vast empire among themselves, but still remain within the limits of his government. To him they look up with filial dependence, and in him acknowledge their origin: morning and night they offer to him, as it were, their adorations, for from him they first derived their life, and still continue to derive it; thus he always reserves to himself the supreme authority of a parent. Let us, however, now pass from the planets, and while leaving them to their rovings, confine our attention to the globe we inhabit. In so doing, let us accompany it from the place of its origin to the orbit which it finally attains. Let us see in what manner it invests itself with ether, air, water, and the other matters of which it consists; let us mark the changes it undergoes in its progress towards its final orbit, and through which, by means of so many series, it attains to such variety. Let us consider the way in which, by means of changes and contingencies, the seeds of so many things were produced, and our earth became so beautiful, that nature wondered at herself because she possessed such delightful variety; and she made the inhabitants sharers in these.

So far the infant has been left naked, unclothed with any living vesture; and being of recent birth, is still in its utmost

simplicity, consisting entirely of fourth finites; thus it is homogeneous, uniform, and perfectly regular in its figure. As yet there is nothing heterogeneous in it; nothing cold to contend with anything hot; nothing of one kind in opposition to anything of another; nothing moist in opposition to anything dry; nothing soft in opposition to anything hard: it has weight without weight; it does not yet contain within it the seeds of things and which are discordantly joined. The earth continues to retain its primeval form; and, as the poets have sung, from the surface to the centre one and the same undiversified aspect. In fact, were we to indulge in the language of the ancients, we should say, that the family of gods had not yet been born; Jupiter could not as yet enter into wedlock with Juno, for as yet there was neither ether nor air; neither had Venus or Love, so famed by philosophers and poets, yet made her appearance; much less any semi-deities. Phœbus and Time alone existed, and even these in their infant state. Let us, however, pass to graver and more useful considerations.

1. The fourth finites, of which the infant earth consisted, could not possibly actuate or finite themselves any further; that is to say, they could not form themselves into similar larger finites, except near the surface; not, however, between the surface and the centre, because here they had no room to unfold themselves. Even near the surface they could not actuate themselves, because the vortical element or first elementary particles flowed round, pressed upon and impeded them, and whenever they were set free, immediately absorbed them. The earth thus floated in an elementary volume, or in the vortical element of the sun, by which alone it was now enveloped and equally pressed on every side. That they could not actuate themselves, follows from the principles we have before laid down. In order for them to become actives, a space was required, which was either empty or non-resisting, in which, as actives, they might run freely and revolve with all their force, or without hindrance. In the present case, however, there was an element which served as an obstacle to them, and which pressed upon the earth in all directions.

Having, therefore, no power to actuate themselves, they were compelled to press upon the surface of the earth, although in every fourth finite there remained the force and power to be able to move still further. Moreover, near the sun there were first elementary particles in their highest degree of compression, which consequently pressed upon the earth and its individual parts in greater abundance and force than elsewhere; but the case was otherwise after the earth had progressed to a greater distance into the solar vortex, where the same elementary particles, exercising a less pressure upon themselves or upon the earth, received them and allowed them greater scope for finiting themselves. Between the surface and centre of the earth, however, they had no room to unfold their forces, or to become aggregated, or to divide themselves into other finites; as we may see illustrated in cases which come within the limits of our own experience. Water, for instance, whose surface we distinguish from the surrounding atmosphere, evaporates only at the surface, not within its volume. The same is the case with mercury, as well as all liquids which at the surface are pressed upon by the atmosphere. In the interior, however, the volume itself prevents the possibility of such phenomena, as the pressure in the volume is according to the depth. This, however, did not prevent every part in the new earth from surface to centre, from being disposed into its own proper order.

2. These fourth finites flowed more freely near the surface of the earth, and there only could dispose themselves and have free scope for any given motion; this is a consequence of the former proposition. They were, therefore, occupied there by the particles of the circumfluent element, and formed into new elementary particles, which interiorly contain a small volume of the particles of the first element, the fourth finites constituting the surface; that is to say, those finites of which our new orb consisted. These new elementary particles are the same as the ether. We see this illustrated in the case of water and every fluid which evaporates only at the surface. The fourth finites or individual parts of the earth possessed their own inherent and

natural force, by means of which they had a tendency to motion ; and especially at the surface where the elementary particles of the fluid vortex were contiguous and in perpetual motion, particularly in the neighbourhood of the sun. From this twofold cause they formed themselves into new particles, in which the elementary particles of the vortex were enclosed, the fourth finites constituting the surface ; corresponding to the case of the first and second elementary particles round the sun, of which we have spoken in part i., chap. vi., art. 3 ; and chap. x. Thus we have new elementary particles entering into the system and constituting a third element, or the ether. It therefore follows that in course of time there arose a large number of these elementary particles or ether, for a large volume of elementary particles may arise from a small volume of finites ; and therefore the new earth experienced a considerable diminution at its surface before the whole sphere of ether became perfectly formed around it.

3. Because this new earth continually rotated round its axis, and exposed its whole surface once every day to the sun, these new elementary particles took their rise all over the surface, were generated over the whole circumference, and did not proceed from one part more than from another ; whence the earth, however, diminishing at the surface, retained its spherical or elliptical form ; and since it had an axillary rotation, the elementary particles produced were carried into a certain motion, the same as that of the earth. And these being, as it were, bound together by means of this motion, they disposed themselves round the earth, and did not suffer themselves to be carried in any other direction ; and this took place until the sphere grew from its primary to its final form. Because our earth, which consists of fourth finites, is a single large finite or a compound of individual finites, it has, therefore, an axillary motion ; according to the principles we have already frequently mentioned. Immediately on its leaving the sun it revolved round its axis, sporting as it were and gamboling in orbital motions like a child around its parent, and thus running off far and wide into the vortical field. This axillary motion occasioned an equal

absorption of the surface into elementary particles, inasmuch as it diurnally exposed every point of the surface to the sun, and the nearer it was to this luminary, the more easily could the solar rays spread over the surface, the comparative magnitude of the earth, when in close proximity with the huge solar sphere, being insignificant. If, therefore, the surface were everywhere uniformly diminished, its spherical figure would be preserved; but if the diminution were greater in the warm zones and those more directly opposite the sun than in the cold and oblique zones, the figure would be elliptical. Another consequence of the diurnal rotation of the earth is this; that the ether immediately on its origin took the same motion as the vortical element surrounding the sun; and from the first moment of its existence formed itself into a sphere, whose centre was the earth, its motion being assisted by the element of the solar vortex, which revolved in a similar manner. Now because the gyratory motion of the ethereal sphere began from the moment the sphere originated, when the amount of ether was still small and extended only to a small distance, it follows that the element continued to revolve during its increase so long as the centre was active. But because the element of the solar vortex had a strong tendency to spiral gyrations, it had a vortical gyration at a great distance from the earth, in agreement with the theory laid down in our first and second parts; and as it was not possible for the ethereal element to extend to this distance, the real vortex surrounding the earth seems to consist of the element of the solar vortex.

4. The ethereal particles are much larger than the first and second elementary particles: the two kinds of particles differ also in this respect, that the ethereal possess an internal space consisting not of actives but of elementaries, while the first and second elementary particles consist of pure actives, as we have before stated. Consequently the two kinds of particles are not similar in figure, but the ethereal are exactly spherical, while the first and second elementaries have poles or polar cones. That the ethereal particles are much larger than the first and second

elementary, follows from the fact that they are composed of finites on their surface and of elementaries enclosed in the space within ; for if elementaries are enclosed in the particles of ether, the size of the ethereal must very greatly exceed that of the elementary particles. We have above shown that the difference between the two consists in this, that the enclosed space of the ethereal particles does not consist of actives but of elementaries. Thus there are as many active spaces as there are elementary particles enclosed, because in every first elementary there is an active space. The ethereal particles thus partake of both principles, the active and the passive, and deserve the name of elementary. That they are of a spherical form appears from this, that interiorly the particles are in contact, or a small volume of definite entities forms an extense in which all the particles are in contact. Thus it is that the enclosed arrangement by contact gives form to the surface ; and that the form of the surface is not due to the individual parts, as in the case of the first and second elementaries, in which there is no contact, no resistance, but only pure activity. And because the characteristic of an element is that it exercises a pressure according to the situation and motion of its parts, namely, equally in every direction, we are obliged, therefore, to conclude that in consequence of this pressure the form of the enclosed particles is spherical.

5. These new spherical particles cannot but be in perpetual motion. The first enclosed elementary particles arranged themselves in every way suitably to the motion of their composite or the ether, and with a greater exactness proportionate to the amount of motion in the ether ; that is to say, their arrangement is according to the degree of motion, and in order from the centre to the circumference. Of the elementary particles thus enclosed, those at the centre are more expanded than those near the surface. The ethereal particles are in continual motion, because they are perfectly spherical, yielding, and elastic, and because they touch one another only at one point. The only thing that can mechanically impede and retard their motion is that of contact at several points or at a greater angle. Now in a sphere there is no angle

but a general or circular one: there is nothing more suited to motion than this. We have frequently shown in our first and second parts that the first elementary particles are arranged according to this motion; and that in a greater degree of motion they become more compressed; therefore in the case of the ethereal particle, as its greatest motion is at the surface, it is, consequently, more compressed at the surface and more expanded at the centre. Now because this spherical composite body is moveable not in one direction but in all, it follows that the ethereal particles accommodate themselves to all. There is also a certain centrifugal force which urges them from the centre to the circumference, and if the motion be equal in every direction, the elementary particles are driven to assume a more erect position towards the surface. This we may see experimentally verified in an exhausted glass receiver or cylinder to which an axillary motion is given, and in which central capilli or threads are found to stretch towards the surface. The case is the same also with other fluids and solids made to assume a rotatory motion. It therefore follows that the central particles are more expanded than those on the surface. We may here add also, that the enclosed first elementary particles assume the position which is most natural to them, and the more so in proportion as the motion of the ethereal particle is more intense; and that in this position they do not partake of the motion of the surface or of the whole particle.

6. The ethereal particles thus formed can subsist under any kind of motion, and with perfect aptitude to it; their surface is expanded and kept in equilibrium between two forces, or undergoes as much from without as from within. For within, it is equilibrated, as we have said, by its elementary particles; without, by circumfluent elementary particles of the same and also of a secondary kind, and again by a reciprocal pressure. The superficial expanse lies, therefore, intermediately between two or more forces, just as in the case of the aqueous superficies of which vapour consists. This subject, however, we have already treated in chap. vi., art. 5, part i.

7. The ethereal particle thus formed and equilibrated is most highly elastic, and hence deserves to be called elementary. Its elasticity, however, is due to the enclosed first elementary particles, in which the primitive elasticity is latent. By aid of the enclosed elementaries it is capable of expansion, compression, and of yielding. It derives its elementary nature from the first elementary particles, and is thus endowed with the character of an element. The enclosed elementary particles being elastic, so also is the volume of the particles, according to chap. vi., art. 6 and 25, part i., hence also their compound is elastic; the particle also possesses both an active and a passive force, or each of the first principles. From what we have said it is evident that it owes its elasticity solely to the enclosed elementaries, and not to any space consisting of pure actives.

In every degree of compression and expansion it is nevertheless exactly spherical, and the more so in proportion to the greater degree of motion which it experiences. It is in equilibrium between two forces, the element pressing both from without and within. It can therefore be in equilibrium between two elementary forces only in a manner adapted to the natural pressure of the elementaries, or to the forces acting on both sides, the action of which is similar, both in a greater and less degree of compression; in a greater degree the action is more intense, in a lesser more relaxed; in the greater degrees of compression, therefore, the figure is more exactly spherical. Now since the form of the surface is due to the contiguity of the enclosed particles, and of those which are circumfluent, it follows that the surface cannot but be spherical; the cause being always the same, of course the effect is the same. See part i., chap. vi., art. 18.

8. The ethereal particles and the first elementary differ in this, that in a higher degree of motion the former expand themselves more and more, as it were, and become less elastic, and consequently offer a greater resistance to any external force. On the contrary, in a higher degree of motion the first and second elementaries are more compressed, and when compressed, they become less elastic, and in this case also offer a greater resistance

to any external force. That in a greater degree of motion the ethereal particles, as it were, expand themselves, see art. 5-7. Under the same circumstances the first and second elementaries compress themselves, or withdraw into themselves, as it were, see chap. vi., art. 17, 20, 21, 22, part i. It therefore follows that in a state of expansion the former exercise a greater resistance, and the latter a less; and contrariwise; consequently that the expansion of the particles of ether has a greater tension in a greater motion, and less so in a less motion; that the tension of these particles is always proportioned to their degree of motion, and consequently in every degree they have a greater or less tension. For since their tension is according to their degree of motion, they may have a greater or less tension in one and the same small space. Thus in a cold place their tension may be less because they are in less motion, in a warm place they may have greater tension because they have a greater motion; the particles, therefore, would have less tension in water than in air, and between the parts of one kind of liquid more than between those of another; between the parts of cold mercury less than between those of warm spirit. In the pores of a hard body their tension would be different from what it would be in the spaces between the parts of any element; within one body it would be different from what it would be within another; and so forth. Of this, however, we propose to treat in a work especially devoted to the subject.

9. Under every degree of extension and compression the ethereal particles are most highly mobile; and in their state of tension are most highly active. The more tension they have the more exactly spherical they are; for the enclosed elementary particles have a greater tension, and thus are in contact in a fewer number of points, and become, as it were, highly sensitive to every motion. In this state there is nothing that opposes their motion, nothing that is not highly favourable to it and in mechanical agreement with it.

10. Both by their tension in their greatest state of motion, and the compression caused by an incumbent weight, they may be

brought to such a degree of resistance as to be unable to become more elastic, but like rigid bodies resist every compressing or opposing force. In a state of motion the enclosed elementary particles arrange themselves from the centre to the surface, and take an erect position like radii or crests, by the application of one pole to another, in consequence of which they become harder and more resisting, as we have already shown in our second part. For if each enclosed particle fits one of its poles to the pole of another, then the one rests, as it were, upon the other, and the one being thus supported, as it were, by the other, offers resistance. In regard to their poles they are not yielding as they are in regard to their equators. Moreover, in consequence of this arrangement of the particles, they adapt themselves to a kind of vortical motion; that is to say, to every motion which takes place reciprocally among themselves, and into which they cannot enter without first taking their natural arrangement as already mentioned. They, therefore, act according to a highly mechanical law; the same, in a word, as the one repeatedly stated above, and which results from the agreement subsisting between the motion and figure of the parts. The greater the motion, therefore, the more are they brought into a position of resistance, or into one of self-protection against any oppressive force. The more erect the situation of the particles the greater is the degree of motion; consequently they cease to be elastic, become hard and rigid, and resist every kind of pressure. The same kind of resistance and rigidity arises also from very great pressure, as will be shown in the sequel, after we have made a few observations on the complex condition and state of the particle under various degrees of pressure. Hence the particles become more rigid and stubborn according to the degree of motion.

11. These particles can expand without motion, and during this expansion they are not rigid but elastic. The more they expand and the less their activity, the more elastic and yielding they become; and the more they are compressed, the less elastic are they. Their expansion is due to a variety of causes; motion is one of these causes, in consequence of which they become more

rigid. For as the expansion of the surface consists in bringing the forces pressing on both sides into equilibrium, so there are causes of expansion arising from the same principles also, which may be made a subject of enquiry ; as for instance, whether the pressure of a higher volume of particles is less, or if the superincumbent volume is less ; whether the weight pressing from any direction without is less than the pressure of the volume itself. Suppose, for example, any part of a volume be extracted from a given space by the air-pump or by other means, in this case the volume which is left becomes rarer, and consequently the pressure from without becomes less than the pressure from within ; this state is called the rarefaction or attenuation of the volume. Similarly the ethereal particles also may expand, whenever the nearest ones are dissolved, and the superficial matter of the dissolved particles escapes to their surfaces ; for this acts as an immediate cause of expansion, or of the passing of one particle from its place among the others which are in the same equilibrium. To produce the compression of the particles, opposite causes concur, but it will be needless to specify these, as opposites may be easily inferred from those already adduced. It is only in this manner, and from similar causes, that a flask or bladder containing air can be expanded or compressed. By heat and motion you may expand a volume which in a state of cold and rest goes back to its former dimensions ; you may expand it also by removing the circumfluent parts, or by rarefaction ; you may compress it by the increase or condensation of the parts. Thus on a large scale you may see what takes place on a smaller ; in the visible portion of the material world what happens in the invisible ; in the whole machine what occurs in the model. That the particles are more or less elastic according to their degree of expansion and compression, provided neither of these be produced by motion, may be seen in part i., chap. vi., art. 31. In this case the cause being similar so is the effect ; but there is this difference, that the contiguous elementary to which the volume owes its elasticity is within. For if the enclosed elementaries expose their equators to the surface, or if they ex-

perience a pressure in the direction of their equators, the most yielding and highly elastic particles recede into themselves.

12. In the highest degree of expansion the elementary particles may be broken up, and cease to be elementary; but nevertheless the finites, inhering to their surface, and which are now escaping by reason of the disruption, cannot actuate themselves, but must fall into some of the surfaces of the neighbouring particles, and there like finites continue their motion as before in some other surface; so that by the dissolution of the particles and their falling into the neighbouring surfaces, there is imparted to these surfaces the power of expanding themselves further, and occupying more space, so far as the quantity of enclosed elementaries permits. On this subject see part i., chap. vi., art. 14, where the same phenomenon is discussed, together with its causes and effect. The cause of the disruption is a degree of expansion greater than that which the quantity of particles pressing from within permits; or it is a deficiency of the finites that would have occupied the superficial expanse, and which, if rarefied, could not be bound together with one another.

13. The fourth finites constituting the surface of the ether, have a perfectly regular arrangement; extending by continual spirals from one polar point to its opposite; and by reason of this arrangement there is a mutual connection between them; consequently any motion received by this surface must necessarily, in virtue of the contact and arrangement of the parts, diffuse itself around instantaneously, and occupy the whole surface of the particle at one and the same time. In consequence of this spiral arrangement of the parts at the surface, these ethereal particles come to rest with difficulty; more particularly when rendered more rigid by motion; in which case they revolve with the utmost rapidity round a centre, in the same manner as the first and second elementary particles round their axis.

Finites cannot naturally arrange themselves in any other way than spirally, so as mutually to press upon one another according to the mechanism of their figure and motion (see part i., chap. vi., sec. 2. art. 2, 3; also chap. iii., art. 19; chap. iv.,

art. 19, etc.) The finites which create this surface must, therefore, always retain this nature, wherever they are, if they are free; they must have always one and the same nature, because they are under the control of their own mechanism and under the necessity of obeying its forces. Indeed, we find the same cause prevailing here as at the surface of the higher elementaries, where also finites constitute the surface; it is for this reason that they dispose themselves spirally, and this from one point of the surface to another. It is in this manner that they form a contiguous expanse, from which there arises at once a unanimity and consent of the parts to one and the same motion; so that the effort, will, and nature of one are the same as those of another; they have the same state and sensibility. The case is the same with all that have the property of contiguity (see part i., chap. vi., art. 10, 11, 12). We require here only to state in addition, that inasmuch as these finites are raised to a higher power, and are thus made repeatedly derivative, they have a tendency to move themselves not only concentrically but eccentrically, according to what we have said (part i., chap. vii., art. 12); consequently, that they must by their periods change places with the pole at this spherical surface. But not to pursue this subject, lest we should dwell too long on the deeper mysteries of nature, we may observe that the effect of this spiral arrangement is, according to our principles, this general one, that the finites impel themselves into a given motion, and in the case of the particle we are considering, into a central motion; just as the first and second elementary particles were put into an axillary motion; on this subject see chap. vi., sec. 2, art. 6, 8. Hence the ethereal particles have a perpetual central motion, more especially if the finites change places as to their poles; they have also the highest degree of central motion, if, in consequence of its motion, the particle be in a state of tension, and in consequence of their slight degree of contact one offers no impediment to the other. When elementary particles of this kind, therefore, are in motion, they are for this reason most highly active. For the parts of the contiguous space within are arranged

with a view to motion, nor does a looser connection of these parts offer in any way any reaction ; for it is in every respect fully subject to the pressure of the surface.

14. The surface of an ethereal particle may be doubled, tripled, or multiplied in various ways within, and this too during its state of compression ; but the part of the surface which recedes toward the interiors is differentiated into a new spherical formation, each sphere being similar to the larger ; and in a greater degree of compression, the spheres thus formed within are multiplied, and, being thus multiplied, they dispose themselves from the surface toward the centre. That a surface consisting of finites may be doubled and multiplied, we have shown in part i., chap. vi.., art. 19 ; and inasmuch as it consists of finites of a similar nature, therefore the effect is similar. The fact that these particles appear to become spherical in a similar way to their larger one, and, as it were, its offspring, arises from this, that there is a volume and contiguous formation within, which occupies space, and that this volume is similar to itself in its greatest and least particles. If there are the same individual parts, the causes are the same, and the effects the same. If finites driven inwardly by compression come into contact with a volume of the same kind, they are by these in motion similarly thrown off and become spherical minute ethereal particles on the surface. Thus these particles are generated within by the larger, in the same manner as the larger are generated from the larger volume. A similar nature and mechanism result in like begetting like, wherever a like cause is present. If any one desires to institute an inquiry into nature by aid of the principle of similitude, he will always find the object of his inquiry, provided he does not seek for similarity in that which is dissimilar. If, therefore, when in the womb of its parent, the progeny begins to occupy space, it will first occupy that which is next to the surface, because it is in that direction that heavy bodies and centrifugal motion tend. Similarly it is the place where it first has its birth, and where are also the more compressed elementary particles which form

it; but the more there are to succeed one another, the nearer to the centre are they compelled to be. It therefore follows that these ethereal spherical particles exerting tension within, are, in the state of expansion of the ethereal particle, again set free, and recede to the surface, and enter into the expanse. For in the expansion of the ethereal particle, all the enclosed first elementaries are also expanded, and consequently those which are enclosed in these small elementaries, and which, when expanded, are in the same manner set free, and recede to the larger surface. It follows also that, in its highest degree of compression, the entire ethereal particle is at length occupied from the surface to the centre by similar small spheres, and thus ceases to be both elastic and elementary, becoming hard and similar to a kind of material finite. For if we proceed by similar relations from one degree to another, so as to arrive at the highest degree of compression, we find the whole particle, occupied by the spherical particles previously mentioned, losing its elementary nature, and assuming a hardness similar to that of a material particle. Hence in a greater and less degree of compression, the particle becomes less elastic, and less elementary, until it finally becomes perfectly hard and resisting. See the parallel to this in part i., chap. vi., art. 21, 22.

15. With regard to the elasticity of the particles, it follows from what we have stated, that the elasticity of the volume is the same as the elasticity of each particle; that the elasticity of a lower volume is equal to the weight of the whole of the higher volume pressing upon it, because the two press and are themselves pressed in proportion to the weight of other particles, and it is in consequence of this that they recede into themselves in the manner previously stated; in order, therefore, that they may sustain the superincumbent weight, their elasticity must be equal to the force and weight of the superincumbent volume. It follows also, that the elasticity of the compressed volume of these particles is to the elasticity of the expanded volume reciprocally as the volumes; and thus that the elasticity of the compressed volume is rendered stronger than that of the ex-

panded volume, in proportion to the mass or weight of the superincumbent volume. It does not, however, follow from this, that the density of the lower volume of ether is similarly proportioned to the density and weight of the superincumbent volume; for the particles of ether, as already observed, become more and more rigid, or less and less elastic, according to the amount of pressure, until they no longer give way to pressure, as was the case in their state of expansion, a state in which they were in a highly compressible condition. As above remarked, it does not follow that the density of the volume of the ether is similarly proportioned to either the density or weight of the superincumbent volume. The actual ratio of the one to the other will be stated in our theory on this subject.

16. The ethereal particles mutually press upon one another according to the altitude or weight of the superincumbent volume. Their pressure is exerted equally in all directions, upwards, downwards, and obliquely. Their pressure is also proportional to the side or area at any given angle. The elastic force of the particle is exerted also in every direction. They exert also a similar pressure upon the interior parts of any hard body, the pores and interstices of which they are able to enter and permeate. It is in this way that they keep the smaller parts in connection with one another. This has already been in some measure explained in part i., chap. vi., art. 47, 48, 49. We here add, that the ethereal, like the higher elementary particles, are similar to themselves in respect to figure under every degree of pressure. They are, for instance, perfectly spherical, both when compressed and expanded; for the enclosed element acts in all directions toward the surface, and this the more or less, according to the degree of pressure, for it always strives equally toward every point or angle of its surface. And because it thus reacts equally at all angles, in the same degree in which it is reciprocally acted upon either by pressure or by any other force, there is, consequently, a perfectly equal reactive pressure in all directions, and in the ratio of the weight of the superincumbent volume. This reactive pressure also is the

greater in proportion to the number of points upon which it acts, or in proportion to the number of points in the area upon which it acts; that is to say, it is greater on a larger than on a smaller area; and because the reaction is equal to the elasticity of the particle, therefore its entire elasticity is exerted in every direction, and the effect produced is proportional to the elasticity. Now because this particle owes its elasticity to the enclosed particles, which are themselves most highly elastic, we have therefore the same ratio of elasticity in the enclosing particle as in the enclosed particles. On this subject, see part i., chap. vi., art. 6, 7, 31.

17. The motion of the volume of the ethereal particles is the same as the motion of the particles individually. This motion is perfectly equal in all directions; differing in this respect from the motion of the volume of the first and second elements. Every particle contributes its own share to the motion of the volume; and therefore, from the figure and mechanism of the particle we may ascertain the nature of the motion of the volume of particles, and from the figure and mechanism of the motion of the volume, the nature of the particle. On these subjects, however, we have dwelt almost too long in the first and second parts, and, therefore, all further explanation of them may be omitted here. We must bear in mind, however, that the difference in the general motion of the particles is the same as the difference in the figure of the particles. The ethereal particles, because they are perfectly spherical, by their motion spread spherically, or the form of their motion is the same in every direction; that is to say, they form by their motion a volume perfectly similar to itself, and their motor nature becomes plain even to the senses.

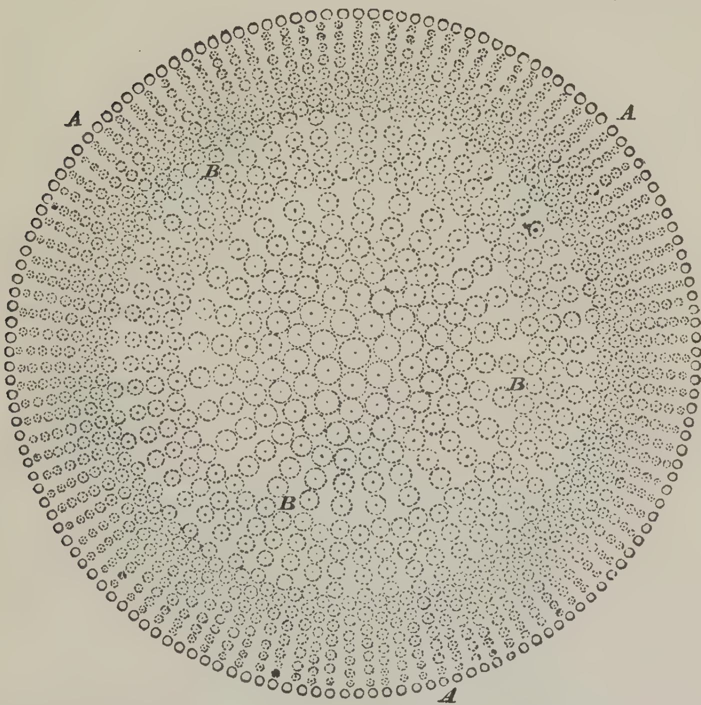
18. Particles moved in volume nevertheless preserve their equilibrium with one another in their relative positions, and cannot be forced out of their equilibrium or natural state by any general motion. Consequently, in a single volume in motion, there may exist innumerable other volumes, even indeed equal to the number of centres or causes of motion, or to particles.

Nevertheless every single volume arising from motion, diffuses itself and is formed from its centre with perfect uniformity and similarity, according to the geometry of the parts; that is to say, spherically. The motion of the volume is the same as the common motion of the parts. It is, as it were, a large particle formed by means of motion, one particle acting upon the one nearest to it in the ratio of its elasticity and pressure; consequently one does not interfere with the natural position of the other, all the particles maintain the situation which they hold relatively to those nearest to them, nor does one undergo any change of place, figure, or space, apart from any other. The volume is, as it were, a large connected whole, whose motion is that of its particles. Thus the particle in motion remains always in its natural state; no particle loses any of its equilibrium, but contributes to the general equilibrium. But if every part of the volume in motion, is in its own state and remains similar itself, there is nothing to prevent one volume from being formed within another, other volumes within these, and so on continually; for as many may be formed without any disturbance of the equilibrium as there are centres and individual parts. Thus nature is identical both in causes and in effects; and so in effects causes reëxist, and no effect is produced without at the same time a cause; that is to say, nature is the same in the cause and in the effect. In this way she operates, as it were, purely by causes, and is always in her cause in order that she may be called the cause of her effect, the posterior may be called her prior, what follows from first principles her primary; thus that she may be always one and the same, and preserve the most perfect simplicity. In the immensity of the heavens nature sees scarcely anything but her cause, origin, and first principle, and beholds herself in it as in her simple form. It is only by degrees, times, and relations that she confounds us; that is to say, it is her vastness and minuteness, and hence her profuseness and variety, which overwhelm our senses.

19. Let us now consider a sketch of this particle in order by a representation to obtain a clear idea of its nature. A single

ethereal particle in the highest degree of extension or motion is represented in fig. 107. The surface is formed of a single series of finites A, A, A; within are the first elementary particles B, B, B, having a position, according to their poles, from the centre to the surface. In the middle they have the highest degree of expansion and become gradually compressed toward the

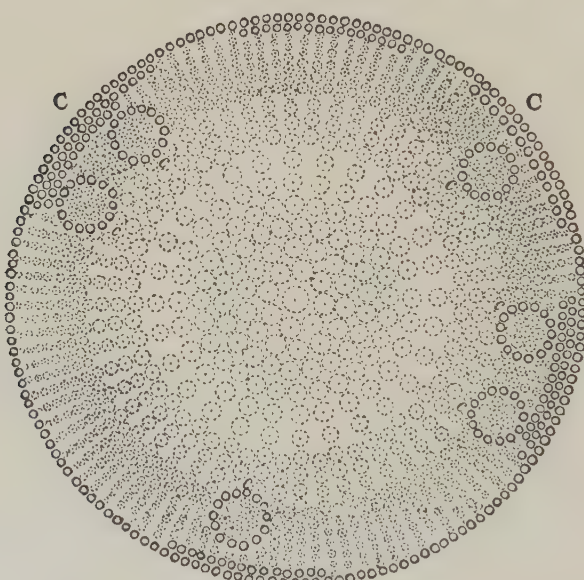
Fig. 107.



surface, where they have least elasticity. Should this particle experience further tension, the connection of the finites at the surface would cease, and also that among the neighbouring particles. Thus in fig. 108 we see the particle under some degree of compression, but still in a state of motion. In this case the surface begins to exhibit a certain complexity and multiplies its rows, as in C, C, C; the same surface also undergoes a spherical arrangement, as in *c*, *c*, *c*, *c*, *c*; in the interiors of these there is enclosed a volume like that which surrounds them.

These spheres then are contained in the hollow of the larger; but because the elementaries which they enclose are subject to almost the same degree of pressure as those which are without, although there must be a slight difference between the two, it follows that the interior elementaries expand concurrently with the exterior, and the spheres are destroyed, and betake themselves in their free state to their parent surface. The particle is further shown still more compressed in fig. 109, where the

Fig. 108.



spheres are greater still in number, but are near the surface, as in *g*, *g*, *g*, *g*, *g*, *g*. In their state of highest pressure however, as in fig. 110, the spheres *n*, *n*, *n*, *n*, *n*, *n*, extend as far inwards as the centre. In this state, because the first elementaries are almost all consumed, in forming these spheres, the particle ceases to be elementary in consequence of the loss of its power to yield and of its elasticity.

20. If a volume of ethereal particles, flowing from any centre against unbroken equidistant surfaces, passes through any hard body or its somewhat free passages, so that the motion of the

flowing ether may be continued from the other side in such a way as to maintain the same course and action, then the body is in this case transparent. If the volume passes through unevenly, so that the motion is continued from the other side

Fig. 109.

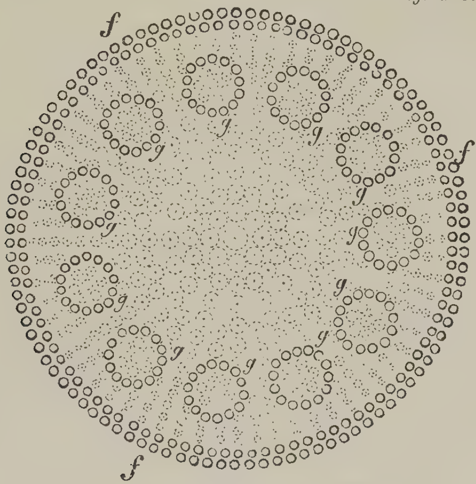
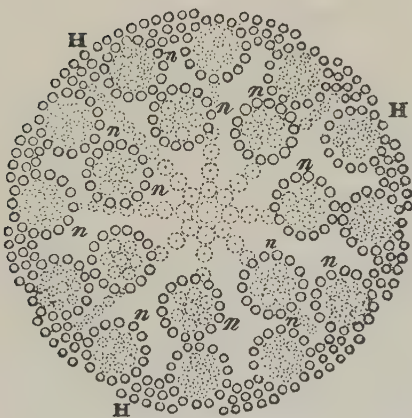


Fig. 110.



variously, the direction of the current undergoing a change, then the body is white in colour. A volume in motion extends itself directly from the centre like radii; and where it cannot penetrate, it is reflected, and this too at a certain angle; just as all other elastic spherical bodies are deflected from any other

elastic or hard body; if, however, the volume passes through, it is inflected and refracted at the same angle of incidence. It is at this point that nature begins to unfold her operations and to present herself to the eye in manifold forms, although she still remains identical, and only going forth, as it were, from a certain centre, forming peripheries at a distance, diffusing herself to as great a distance as the yielding character and compliance of the particles permit. Throughout the whole circle, however, where nature disports with her colours, we find her simply speeding directly from a centre and extending around like radii, in the manner of continuous surfaces. If she meets with a body, reflection takes place at a definite angle, and if she passes through it, inflection or refraction takes place.

Motions may originate in various ways, or may go forth from their centres in different ways; they may extend more or less widely, from a space or centre greater or less, or from spaces or centres of various figures. A motion may in this way be more or less curvilinear, more or less extensive, slower or swifter; it may in its course render itself similar to the moving force, because it may pass into space from innumerable centres. Thus within one volume in motion there may be motions similar and dissimilar, concordant and discordant, or more or less harmonious; and all these may pass at the same time through the organs of the eye, and simultaneously and similarly present themselves to the mind. Similar and harmonic motions may unite, and more powerfully move their mechanical organs; dissimilar motions may be reduced, as it were, to their faintest forms, and nature may thus with infinite variety act upon the senses and the mind. If I could reduce all these things to rules, we should then know the nature of the organs of sight, and the definite entities from which, as from centres, the ether directly, obliquely, and reflexively turns itself. These subjects, therefore, must be specifically treated, or otherwise, although in the midst of colours and light, we shall be in darkness. In first principles we cannot arrive at the knowledge of effects, without some agent, or without intermediates. The effect is colour; the agents are the bodies which

produce the motion ; the intermediates are the organs of sight. This subject therefore we reserve for a specific treatise.

21. The doctrine of the ether, or the phenomena caused by ether, may be reduced to the following statement. Motion diffused from a given centre through a contiguous medium, or volume of particles of ether, produces light ; for as a result of this motion the ether is reflected from every particle it meets with, and thus the form of an object is presented to the eye. The central motion of the particles of the ether produces not only a rigid expansion of every particle, but also heat ; and if this motion be urged from the centre to the circumferences, it causes light together with heat. If, however, it be urged from centres toward circumferences so as to become a local motion, but without the central revolution of every particle, it occasions light without heat. There are minute corpuscles which resemble a kind of effluvia, and which are so small as to be able to move only a volume of ether, but not a volume of air ; these, if spontaneously moved, excite light to a certain distance. If they are not spontaneously moved, but put in motion by means of the tremulation of the parts in any hard body where they are, then light also is produced, and also electricity, so long as the tremulation continues. That the motion of the ether, when diffused in all directions from a given centre, or when diffused to equidistant circumferences, produces the phenomenon of light, is evident from what we have stated. For when ether is put into a general motion or effort towards peripheries, it is reflected from every object it encounters according to its angle of incidence, and forms as many centres as there are objects to meet it. Consequently, the forms and images of things are produced by means of light. This could not be done unless the contiguous volume of ether were urged into such a state of general motion, or effort toward such motion, as we have already mentioned. That the central movement of the ethereal particles causes not only their rigid expansion, but also heat, may be seen in this chapter (art. 8, 9 ,10 ; and chap. viii., art. 9, 10, 11, 15). Since, therefore, local motion, or the effort toward local motion,

in the ether, is the cause of light, and light is the cause of the forms of things being presented to the eye, it follows that light may arise from either heat or cold as a cause.

In regard to phosphorescent light and electricity, I maintain that both have the same origin, that is to say, the ether in which either local motion, or else an effort towards it, is set up. The *ignis fatuus*, as it is called, is merely motion extending throughout the volume or contiguous area of the ether, without any rigid expansion of its particles. For if there be any corpuscles so small as to move the ether only, like the corpuscles or effluvia of the magnet for instance, and which move only the second or magnetic element; then I would say, that this is caused by the motion of these corpuscles or effluvia, and if these corpuscles have a circular motion, whether spontaneously or not, provided there is some cause or other to occasion such circular motion, they immediately put the ether in motion and produce light, without the expansion of any ethereal particle; just as is the case with air, which may be moved in volume and contiguously to a distance without the expansion of any particle, and may thus produce sound. The *ignis fatuus*, therefore, is a local motion of the ether produced by the motion of certain smaller corpuscles, so that the cause of warm and cold light is one and the same. The corpuscles or effluvia we have mentioned may be put into circular motion either spontaneously, that is of themselves or from some internal cause; or else by the vibration of some hard body, in which they are and from which they proceed. Let us at present confine our attention to the second cause, namely, the vibration of the hard body in which they are and from which they issue. We say then that the vibration of this body sets up in a similar way a vibration of the parts of the body, and of the minute corpuscles which are within it and flow around it. In consequence of this tremulous motion of the body, the corpuscles in its interior structure being put into tremulous motion, are urged into circles and eddies, as it were, and at the same time both the ether enclosed in the body and that which flows around. For the ether thus put into motion communicates it

to the surrounding ether, this motion being assisted by that of the small corpuscles which float in the ether and continually issue from the hard body; thus the ether is urged into a whirling motion at a distance from its body, and this causes light, and to a certain degree, electricity. For no bodies exist which are not in some way or other penetrated by the ether, so far at least as their substances and the character of their composition is concerned. By the vibration of the parts of a body, therefore, the motion of the ether diffuses itself to a distance around in the form of a circle. The motion enters into the substance also of the adjacent bodies, and causes these also to have the same current and form of motion, and either draws them toward or repels them from its own tremulous body, and presents to the eye phenomena similar to those of magnetism. But since magnetism consists of an element and effluvia more subtile than those of electricity, which is the result of the motion of the third element or ether, and larger corpuscles or effluvia, that are able to move only the ether; it follows that, in order for anything to be electric and attract very light bodies, a certain circular motion is necessary in the ether, arising from the vibration of certain parts. Because the ether may at the same time enter into the substance of the parts, it follows that the ether thus in motion and penetrating these parts, can bring them into the same circular motion. This, however, would not be the case, if the motion were in the air, which does not easily enter the substance of bodies somewhat hard. Phosphoric light therefore, as well as electricity, depends upon the vibration of the small and subtle parts of a body, from which proceed effluvia of the same nature, putting the ether alone in motion; the longer, therefore, this body can thus vibrate, the more electrical it is; and the more it abounds with subtle effluvia of a similar nature, the more perfect are the electrical phenomena. If the body, although it is vibratory, does not abound in effluvia of this kind, it can give rise neither to light nor electricity. On the other hand, if the body abounds in such effluvia, but its small parts cannot vibrate for any length of time, it is then destitute of light and electricity. The same

phenomena may be produced, if one body is highly vibratory but does not abound in effluvia of the same kind, and another body is not vibratory but abounds in effluvia of this kind; that is to say, if the two bodies differing in this way are rubbed one against another. Much more might be said, but which I omit, as I have no experiments to prove my statements. I might, for instance, enlarge upon the manner in which a sphere becomes formed by these circular motions; upon the character of this sphere; and upon the manner in which the elementary particles are expanded and compressed, how they undulate and become integrated within this sphere, so as to draw and attract into it other and lighter bodies.

22. In this way then we see that our orb became surrounded with an ethereal aura, and in this state bade farewell to its parent sun, and sallied forth into the immense vortical region which lay before it. Still, however far and wide was the range of its orbit, it remained under the eye of its progenitor, under his beams, as it were, and within the boundary of his presence. For between the sun and the earth there is that contiguity of expanse by means of which one can be present, as it were, to the other. However far asunder, therefore, they may be as to situation, they are not so in relationship. The earth, as yet clad only with an ethereal vestment, was now able to present itself to the senses adapted for its perception, beauteous and fair as a newly-wedded bride, differentiated and diversified by colours, provided there were media, or a corresponding organic form, which might adapt its motions to its own nature. As these intermediates and originating entities did not exist, the earth, notwithstanding all its variety, remained, as yet, simple and uniform. Indeed, our orb was hitherto naked, as it were, undistinguished by variety; having as yet only a uniform monotony of appearance and colour, in addition to the azure or celestial tint proceeding from the sidereal expanse with which the earth is surrounded. As yet there was no air, nor any Aurora in this air, which arrayed in her glow of colours might lead on the morning and evening, or open and shut the gates of heaven and earth to Phœbus.

There were neither dews nor clouds, in virtue of which, with her saffron wings, Iris might display her many-coloured arch in the sky; no groves or woodlands bedecked with flowers; no green, violet, scarlet, or roseate hues sprinkled over the fields; no sulphurous or metallic substances to contribute their mineral and vivid lustres; much less any living creature, whose organs being formed to corresponding motions, might receive these external varieties in them, and communicate their pleasurable sensations to the soul.

CHAPTER VI.

THE FIFTH FINITE.

We shall now interrupt the course of the subject with a few observations on the nature of another kind of finite. Indeed, the whole of this volume of the *Principia* seems to deal merely with finites, actives, and elementaries; for as often as we leave the subject, it is again resumed, so that the reader is being continually led over the same ground. In fact, it must be confessed, that while professedly treating of first principles, I can scarcely proceed without perpetually recurring to what has been previously advanced, and saying the same thing over and over again; in the case of derivatives, saying things similar to what we stated in regard to primitives; similarly of composites and simples; of effects of causes. Nature is always, as it were, causal when she is in her effect, and on the other hand in her effect when she is causal; for there is perfect conjunction between both; and for this reason she is always concerned with causes; so that if you seek her in the effect you will find her in the cause. If you seek her when invisible in the visible world, she will never fail you, but will be present and visible before you; she will never elude the eye, nor mysteriously hide herself, but be ever most intimately present, and the constant environment of both yourself and your senses. Let us then inquire into the nature of that finite which we denominate the fifth, in which the point is raised to its fifth degree or power: and in which it is perfectly similar to the other finites of which we have so frequently spoken, differing from them only in degree and dimension.

With respect to the origin of this finite the following conclusion results from our principles :—It must have originated where there

was a quantity of finites of the fourth kind, and where the latter could in some measure unfold and mutually finite themselves. And because these fourth finites could now be only in the planets or here in this earth, and could unfold and finite themselves nowhere else but at the surface of the earth, and not even between the surface and the centre because they had no room there, it follows that these fifth finites must have originated at the surface of the earth, at some distance from the sun, where the pressure of the vortical element was not so great as it was in the vicinity of the sun. We, therefore, trace the origin of the finites of the fifth kind to a position at a distance from the sun and near the surface of the earth; for, as already observed, the pressure of the elementary particles in the vicinity of the sun was too great to allow of this, and, therefore, we must conceive of the fifth finites as having their origin at a distance from the sun. Now because these finites are similar to those already mentioned, so they are endowed with a similar progressive, axillary, and local motion; they are similarly active and passive, and constitute the surface of some elementary particle. That they constitute the surface of a particle of air, and supply fire with its element, it is my intention to show in the sequel.

CHAPTER VII.

THE AIR OR FOURTH ELEMENT OF OUR SYSTEM.

We will now trace still further the course of our globe, and follow it into that vortical region which it traverses as the mighty empire belonging to its parent, and mark the attendant circumstances of its journey, and the various changes it undergoes before reaching its destined orbit. Now it would seem necessary for it to go through an infinite number of changes, before it could be composed of so many simultaneous and successive series. At the moment we are considering, it was bare and plain, consisting only of particles of one kind, and but just environed with the ether. And because, according to our principles, it was bare and plain when it issued forth from the place of its origin, it was necessarily bound to experience a great variety of changes before it could be invested not only with ether, but with air, water, and mineral and earthy incrustations of various kinds; or be so beautifully clothed with herbs, plants, flowers, waving corn, and shrubs as it now possesses. Such changes were necessary also before a rational creature like man could be introduced, as a spouse into the chamber of his partner, into a world abounding with all these delightful things, the result of the many changes the earth has undergone. Let us see then in what manner the earth became girdled with air, in what manner Juno is given in wedlock to Jupiter her brother. For the ancient philosophers represented Jupiter as presiding over the ether, and Juno over the air; and the two as living in conjugal union not far from the earth. They also said that each sprang from the same parent, and that the brother married the sister. Their philosophy does not seem to be far removed from what we are contending for.

With regard to the air it follows from our principles that it could originate only in successive order, after those bodies were produced of which it was to consist.

In the preceding chapter we stated that a new kind of finite arose at a distance from the sun ; that is the fifth finite, which is perfectly similar to those which preceded it ; capable of becoming both active and passive, of entering into the surface of an elementary particle, and of passing through its surface in the same way as the fourth finites pass through the surface of the ether particle. From their connection, then, it follows that air, on its surface, consists of fifth finites, and that within it encloses the first and second elementary particles ; that air is thus very similar to ether, from which it differs only in degrees and dimensions ; for ether and air particles are similar to one another as to their surface. Since fourth finites enter into the surface of the ether, and fifth finites into the surface of the air particle ; and the fifth are of a similar nature to the fourth, they are capable of passing through the surface in a similar manner. Moreover, these particles are similar in regard to their internal space ; for the first elementaries fill and constitute the space of the ether particle, and the first and second elementaries that of the air particle ; and because first and second elementaries are similar and differ only in dimension, it follows that they produce similar effects upon the surface ; they differ therefore only in dimension, and consequently in degrees and momenta. It also follows that the second elementaries occupy the internal space of the air particle, because they are larger and can operate upon fifth finites or those of a greater dimension, and form them into surfaces ; but the first elementaries cannot do this except in relation to the fourth finites.

With regard to their place, the ether and air particles have a similar origin ; that is to say, they are near the surface of the earth, where, as we have stated, the ether particles had their origin. Now all things in regard to our globe must progress in successive order, consisting as it does of particles of a single kind ; everything in it is homogeneous. As yet dissimilarity

has no existence; nature must arise and be multiplied successively from what is similar, the air must, therefore, have originated from the ether. The mode of the origin of air particles is similar to that of the ether particles, that is among the first and second elementary particles, from which the air particles became aggregated into new vaporous states, such as water and other liquids. For the fifth finites cannot issue from the surface of the earth without operating in a manner similar to the ether, and passing into an aërial condition. The air and ether particles are consequently similar in form, and differ only in magnitude and dimension. For the fifth finites have entered into the surface of the air particle, and the first and second elementaries into its internal space; if, therefore, its surface be thus subject to pressure on all sides, namely, by a volume of elementaries of the same kind, the air particles must necessarily be exactly spherical. For when the enclosed volume, conformably to its nature, exerts pressure in every direction upon the surface, and upon this surface there is an equal pressure from without, then the ether particles exert pressure also from without, and it therefore follows from reason and experience that under every degree, both of expansion and compression, they have a spherical form; nor can they in any manner recede or be forced out of this figure, as long as the elementary particles which are without and those which are within retain their elementary nature, so as to exert pressure equally in all directions upon the particles with which they meet. Since, therefore, both the ether and the air as to their origin, locality, and mode of origin, also as to their figure, are so similar, they may be said to be akin to each other, and according to the philosophy of the ancients, it may be said that the sister married the brother, and dwelt with her in conjugal union in one and the same place.

Since the ether and air particles are similar to each other and differ only in dimension, all the qualities of motion and figure of the ether particle are applicable to the air particle, and may be summarised as follows, provided we bear in mind the difference in regard to degrees and dimensions.

1. In the course of time there was produced a large number of these elementaries or air, since from a small volume of finites a large volume of these elementaries may originate; and with a continual decrease of surface our new world considerably decreased in magnitude before the whole atmosphere around it could be perfectly formed.

2. As this new world kept continually rotating round its axis, and in the course of a day exposed the whole of its surface once to the sun, so these new elementary particles, which originated in its surface, were generated throughout its whole extent, and did not go forth from one part more than another; and thus our earth, however diminished in mass, still retained a spherical or elliptic form. See chap. v., art. 3.

3. These spherical particles could not but be in perpetual motion. The first and second enclosed elementary particles disposed themselves according to the motion of their composite or air; and this the more easily and readily in proportion to the greater motion of the air; that is to say, they arranged themselves according to the degree of motion in an orderly manner from the centre to the circumference; the elementaries thus enclosed were more expanded at the centre than those at the surface. These enclosed elementaries were thus in their natural situation; a situation which became the more natural in proportion to the intensity of the motion of the particle. In this situation also they were not sensitive to the motion of the surface or of the whole particle. See chap. v., art. 5.

4. The air particles thus formed could subsist with a perfect adaptation of their forces one to the other, under every kind of motion; their surfaces were equilibrated and expanded between two forces, being subject to as much pressure from without as from within. See chap. v., art. 6.

5. The air particle thus formed and equilibrated is highly elastic, and is properly called elementary. It owes its elasticity, however, to the enclosed first and second elementaries, in which the primitive elasticity is latent. It may thus be expanded, compressed, and may yield, simply by aid of the enclosed ele-

mentaries. Still under every degree of pressure and expansion it retains an exact spherical form; and the more intense their motion the more perfectly spherical are they. See chap. v., art. 7.

6. The tension of the expansion of the particles of air is greater under more rapid motion, and less when the motion is slower. These particles are always in a state of tension according to their degree of motion, and thus under every circumstance have a greater or less degree of tension. Similarly under every degree of expansion and compression, they are most perfectly mobile; but in their state of tension most highly active. See chap. v. art. 8, 9.

7. Both in their state of tension as produced by the greatest motion, and their state of compression as produced by a superincumbent weight, they may arrive at such a degree of resistance as to be no longer elastic; but like hard bodies may resist every compressing or assailing force. See chap. v., art. 10.

8. Even without motion they may be expanded, and in this state of expansion, produced without motion, they are not rigid but elastic; the greater their expansion and rest, the more elastic and yielding are they; while the greater their compression, the less their elasticity. See chap. v., art. 11.

9. In their highest degree of expansion they may undergo disruption and cease to be elementaries; but the finites which occupy the surface and escape in consequence of the disruption, cannot actuate themselves, but must immediately pass into the surfaces of the neighbouring particles, and there continue their motion in another surface like finites as before; thus, by the dissolution of the particles and their passing into the neighbouring surfaces, the neighbouring particles have the power of further expansion, and of occupying as much more space as the quantity of enclosed elementaries permits. See chap. v., art. 12.

10. The fifth finites, constituting the surface of the air, are arranged in the most regular order from one polar point, as it were, by continual spires to the corresponding opposite point; and in consequence of this arrangement of the finites there

is a mutual connection between them; hence it follows that a motion received by the surface is necessarily diffused instantaneously, in consequence of the contiguity and arrangement of the parts, and simultaneously occupies the whole surface of the particle. By reason of the spiral arrangement of the parts in the surface, these air particles are with difficulty brought into a state of quiescence, particularly when rendered more rigid by motion; nor can they help having a rapid central revolution in the same manner as the first and second elementary particles rotate round an axis. See chap. v., art. 13.

11. The surface of the air particle may be doubled, tripled, or variously multiplied interiorly, and this during a state of compression; but the part of the surface which recedes toward the interiors is formed into new spherules similar to the larger; while in a greater degree of compression these spherules formed within, are multiplied; and being thus multiplied they dispose themselves in a direction from the surface to the centre; thus these globular particles, which during their expansion are interiorly in a state of effort, are again set at liberty, recede to the surface, and enter into its expanse. It also follows, that the air particle during its highest degree of compression becomes at length entirely occupied by small similar spheres extending from the surface to the centre, and ceases to be elastic and elementary, becoming rigid and similar to a material finite. See chap. v., art. 14.

12. The elasticity of the volume is the same as that of each particle, and the elasticity of a lower volume is equal to the weight of the whole higher and incumbent volume; for it is according to this incumbency that they exert and receive pressure. It is by reason of this incumbency that they recede into themselves in the manner we have mentioned; therefore, in order for them to sustain the superincumbent weight, the elasticity of these particles must be similar to the force and weight of the superincumbent volume. It follows also that the elasticity of a compressed volume of these particles is to that of a dilated volume, inversely as the volumes. The elasticity therefore

of the compressed volume is rendered greater than that of the dilated volume, in proportion to the mass of the volume or amount of pressure. Still it does not follow that the density of the air below is similarly proportioned to the density and weight of the superincumbent volume. See chap. v., art. 15.

13. The air particles reciprocally press upon one another according to the altitude or weight of the incumbent volume. Similarly, they exert a perfectly equal pressure in all directions, upwards, downwards, and obliquely; as also a pressure proportional to the side or area opposed to them at any given angle, and thus the elasticity of the volume acts in all directions. See chap. v., art. 16.

14. The motion of the volume of air particles is the same as that of the particles themselves, and is perfectly equal in all directions. Every single particle also contributes its own share to the motion of the general volume. See chap. v., art. 17.

15. When the air particles move in volume, they nevertheless preserve equilibrium among themselves, and remain in their relative positions; nor can they by their general motion be forced out of their equilibrium or natural state. Consequently, within one volume in motion there may exist innumerable volumes; as many indeed as there are centres or causes of motion, or as there are particles; and yet every single volume arising from motion diffuses and arranges itself from its centre in a perfectly uniform and similar manner, according to the geometry of its parts; that is to say, in a spherical form. The volume of air particles, however, moves much more slowly and to a much smaller distance than the volume of ether particles. See chap. v., art. 18.

16. The air volume when in motion extends itself directly from its centre like radii, and when meeting with any obstacle which it cannot pass through, it is reflected and rebounds according to the angle of incidence, like all spherical elastic bodies when impinging upon another elastic or hard body. See chap. v., art. 18.

17. Because between the ether and air there is a difference in regard to degrees and momenta, it will follow that the membranes of the body that are organized to synchronise in their motions with those of the air, such as the membranes and tympana of the ear, will be coarser than those which receive and synchronise with the motions of the ether; such, for instance, as the eye; and that the organs which carry the motion from the coarser membranes to the more delicate will be of a different kind. Whatever the eye perceives in the ether, this the ear perceives in the air; whatever the ether presents to our organs by means of colours, the air presents to us by means of modulations and sounds. Thus nature is always the same, always identical with herself both in light and in sound, in the eye and in the ear; the only difference being that in one she is quicker and more subtle, in another slower and less subtle, exhibiting herself to our several senses by means of her various degrees and momenta, and being as perceptible to sense in one medium as she is in another. How admirable are the varied and sportive movements of nature! How charming and delightful does she render herself solely by her variety in the motions of her elements; being as beautiful in the ether by the play of her colours as she is harmonious in the air by the modulations of her sounds! What gratifications does she afford us in the diversified operations of her living machinery!

In addition to what has already been said, we may observe that in chapter v. we have also stated with regard to the ether, that within one volume in motion there may be similar and dissimilar motions, concordant and discordant, more harmonious and less harmonious, all of which may simultaneously traverse the organs of the eye, and simultaneously and similarly present themselves to the soul. See chap. v., art. 18.

Since the air is similar to the ether, the air particle may be represented by the same figure. Thus in fig. 107 (p. 215), we may see an air particle in its highest state of expansion. A, A, A, A, are fifth finites; B, B, B, B, are first and second elementaries extending from the centre to the surface and erect as to their

poles. In fig. 108 (p. 216), the same particle is represented as under a degree of compression in which small air spherules are produced within; in fig. 109 (p. 217), the particle is in a yet higher degree of compression; and in fig. 110 (p. 217), the compression is the greatest.

CHAPTER VIII.

FIRE, OR THE ACTIVES OF THE FOURTH, FIFTH, AND FOLLOWING FINITES.

We have now described the earth as at length clad with ether and air vestments, and thus issuing forth into the vast region of the solar vortex, encompassed with elements of two different kinds; it is no longer, therefore, in that state of nakedness in which it first came forth from the womb of the solar chaos. We are now introduced to Jupiter and Juno, the two principal deities described by the ancient poets and philosophers; and we have seen how the sister has become wedded to the brother. As yet, however, Jupiter brandishes no lightnings, he is not armed with the fire with which he is to make his entrance into the chambers of Juno; there are no torches as yet to precede his steps. We come now to explain, therefore, the nature of the fire of our earth; the nature of that fire which is subtle and penetrating or elementary, as also the nature of that which is less subtle, or the common atmospherical and culinary fire. Without fire all things would be torpid, neither the air nor the ether would be stirred into motion, consequently without fire or something like it, new series would not be produced to bring the earth to its ultimate perfection, no production and secretion would be effected; there would be no growth of plants from the mineral kingdom; there would be no living creature partaking of the elementary, mineral, and vegetable kingdoms; before passing, therefore, to other subjects, it will be necessary to describe the genesis of fire.

1. From the connection of our principles one with the other, it follows that finites of every power and dimension may put themselves into activity, provided they have space for so doing,

or for running freely, naturally, and without retardation into their respective circles; provided also they are not implicated in any elementaries flowing around, and become convoluted into surfaces or new globular, superficial, or elementary particles. That finites of every kind may be rendered active, provided space be granted them in which to perform their movements and circles, may be seen in part i., chap. v., art. 1, 2, 3, 4, 5, 6, 7; provided also there are no elementaries to divert their course into new particles. On this subject see chap. v., art. 12. Consequently, the fourth and fifth finites cannot put themselves into activity in a volume of the elements of the first and second, without immediately being converted into new elementary, or ether and air particles. For they have no space for their movements, because elementaries are present to impede them, and convolute them, while in the condition of themselves becoming active in new surfaces; as in the case of ether or air when converted into water or other fluids.

2. Now since all finites are similar to one another, as also all elementaries, so also are all actives; nor can they differ from one another except as to dimension, and consequently as to degrees and momenta. Since, therefore, finites, of whatever power and dimension, may put themselves into activity, the actives arising therefrom will be of a nature similar to that of the finites, because possessing a similar derivation. Hence the actives of the first, second, third, fourth, and fifth finites are perfectly similar one to another, and according to their natural state of effort tend to similar eccentric circles. With regard to the actives of the first and second finite, they constitute, as we have already observed, the large active solar space. We have also observed that there are no actives belonging to the third finite, but that all are themselves third finites, and constitute the surface of the second elementary particle. See part i., chap. vii., sec. 2, art. 9. We now come to show that the actives of the fourth finite create subtle elementary fire, and that the actives of the fifth finite, or fifth finites having become active, create the common culinary or atmospherical fire.

3. Since the mechanism and nature of the actives of the first, second, and third finite are similar to the mechanism of the actives of the fourth and fifth finites, and differ only in regard to dimension; therefore, before we treat of the mechanical principles of fire, we must repeat the principles formerly laid down when speaking of the actives in part i., chaps. v. and vii.; otherwise we shall meet with some difficulty in arriving at the knowledge of the two kinds of fire. In order that a clear idea may be had upon this point, I will here transcribe the principal heads of what is there stated on the subject of actives.

All the actives of one kind flow with one and the same velocity, neither less nor greater; they always describe similar circles, nor can they form any either less or greater. Part i., chap. v., art. 7; chap. vii., art. 10, 11.

In the active there is nothing substantial, with the exception of that only which is circumfluent; nevertheless a surface may be represented by motion just as if it consisted entirely of substantials; and there is no point in the surface of the active which can be truly called substantial except the one where the fluent substantial is itself present. Part i., chap. v., art. 8.

Every such active is most perfectly active, and also endowed with a considerable power of acting upon the nearest finites; nor can there be conceived in the surface any point which is not acting by momenta. Part i., chap. v., art. 10, 11.

This surface may, according to the increase of velocity, be represented as more and more like a continuous and finite surface; it has, however, no real dimension, but may be called apparent, imaginary, and a mere surface. Part i., chap. v., art. 13, 14.

When present it acts perpetually upon every finite, and by its presence acts upon the finites and disposes them into a certain motion, situation, and figure. Part i., chap. v., art. 15.

Several actives of this kind may be fluent in one and the same space, without coming into conflict. Part i., chap. v., art. 16.

Several of them together may adapt themselves to any angle and space; and taken collectively may represent any figure.

One surface may apparently cross and cut another, and near one surface there may appear innumerable others crossing, as it were, over this one. Part i., chap. v., art. 13.

Several in one space can rarely be in contact with one another, unless they are in too great abundance; and even if they meet one another, they may nevertheless continue the same superficial circular motion. Part i., chap. v., art. 18, 19.

Actives may occupy an exceedingly large space, and may also flow in an exceedingly small space, even within a surface consisting of finites. Part i., chap. v., art. 20, 21.

Several together in one space possess a greater force of acting than a smaller number; or the force of the active space is increased and rendered the stronger according to the number of the actives. Part i., chap. v., art. 22, and chap. vii., art. 18.

The active of the second finite describes larger circles than the active of the first; and the active of the third finite circles still larger; consequently, the actives of the fourth and fifth finites describe circles larger still. Similarly, the active of the second finite does not flow with so great a velocity as the actives of the first; the active of the third finite flows with a velocity still less; and the active of the fourth and fifth finites with a velocity less still. Part i., chap. vii., art. 7.

The active of the second finite can be in the same space with the active of the first; and the active of the third can be in the same space with the active of the second; the active of the fourth in the same space with the active of the third; and the active of the fifth in the same space with the active of the fourth. Part i., chap. vii., art. 8; also sec. 2, art. 6.

But the actives of the third and first finites cannot be simultaneously in one and the same space, without (in consequence of the difference between their velocities, circles, and dimensions), the circles and fluxions of the first active being altogether disturbed; so that this active would be completely pushed out of the space or become entirely absorbed. Thus, in consequence of the influx of the actives of the first finite, the actives of the third may ultimately lose their active force. Sec. 2, art. 7, 8. Consequently,

the actives of the fourth finite cannot be in the same place with those of the second and first; nor can the actives of the fifth be in the same place with those of the third, second, or first, without (in consequence of the difference between the velocities, circles and dimensions), the circles and fluxions of the actives of smaller degrees being put into a state of disturbance, and either the latter being themselves expelled from the space, or the actives of the larger degrees being occupied and absorbed by the influx of the smaller, and thus losing their activity.

The actives of the third, fourth, and fifth finites do not describe their circles or superficies round one centre or surface, but around various centres; that is to say, the derived actives run into eccentric and not concentric surfaces or circles. The apparent surface of the active seems by reason of this eccentricity to describe another new surface proper to itself; and in consequence of the progression of the centre the actives are transferred to every imaginable point of their space. Part i., chap. vii., art. 12, 13.

Actives cannot form anything contiguous, nor occupy any determinate place; they are thus destitute of all place and situation unless enclosed by finites or elementaries. Part i., chap. vii., art. 14, 15.

They have nowhere in their space the relations of upward or downward. Consequently, in the active space there is no such thing as weight; therefore the greatest space is as light as the smallest. Part i., chap. vii., art. 15.

Actives cannot be said to resist but only to act. A number of actives does not constitute an element or matter; actives, therefore, are not to be considered as elementary particles. Part i., chap. vii., art. 16, 17.

The space which is filled with actives of the first and second finite together, acts more strongly than if it were filled with actives only of one kind. Part i., chap. vii., art. 19. Consequently, the actives of the fifth and fourth finites act more strongly than if the space were filled with only actives of the fifth finite.

4. Let us now come to the consideration of the actives of

which we intend to treat more particularly in this chapter, that is, those of the fourth and fifth finites. Let us consider more especially the active of the fifth finite, which is the cause and origin of our atmospheric fire. With regard then to the active of the fifth finite, it follows from what we have stated, that it is no other than the fifth finite itself set at liberty in a space where it can move freely, like the foregoing actives, in eccentric circles and gyres, and by means of which it may form, as it were, those continuous surfaces, and by its weight and impetus act upon whatever it meets. These fifth finites, however, constitute, for the most part, the surfaces of the particles of air. The same result follows from the active of the fourth finite; for this active is nothing more than the fourth finite set at liberty, or in a space where, like the preceding actives, it can move freely, in eccentric circles and gyres, by means of which it may form, as it were, continuous surfaces, and by its velocity and mass or weight act upon whatever it meets; but these fourth finites constitute, for the most part, the surfaces of the particles of ether, and occupy the central globe of the earth. As I have already treated of these subjects, it will be needless to dwell on them longer; but I would observe only that the actives of the fourth and fifth finites can act upon the objects they meet, with greater force than the actives of a smaller dimension. The fourth and fifth finites consist of a larger mass than the first, second, and third finites, and consequently act with a greater force.

5. The fifth finites cannot become active so long as they occupy the surfaces of the particles of air; and if by chance they should be set free from these surfaces, in consequence of the expansion of the air particles, they cannot become active without immediately passing into the surfaces of the other particles of air; and there, together with their like, taking on a general motion, the same as the fourth finites do in the surface of the ether particles. Part i., chap. vi., art. 14, 27, 28, 29, 30; part iii., chap. v., art. 12.

6. The actives of the fifth finite cannot form any active space except among the air particles by which the space is enclosed

and bounded on every side ; consequently they can form no space among the ether particles ; still less among the particles of the more subtle elements, such as those of the first and second. These actives cannot have any boundaries, but are immediately dissipated unless enclosed by air particles. Similarly, the actives of the fourth degree can form no space except among the ether particles—not among the air particles, nor among the second and third elementary particles—otherwise they are immediately dissipated. From what we have already stated it appears that actives cannot be enclosed in any space unless they are enclosed either by finites of larger dimension or by elementaries. Part i., chap. vii., art. 14, 15. In the present case, however, there are no finites of larger dimension, and, therefore, the actives cannot form any space within the connected circuit of the finites ; this space can be formed only by the air particles upon which the actives can act, and which can resist, confine, and keep the actives within their limits only in proportion to their own dimension. In the fifth finite the point is raised to the fifth power or degree, and hence it is considerable in mass ; so that if the point be represented as 1, and if the first finite, for example, consists of 100 points, then the fifth finite would consist of 10,000,000,000 points ; thus it is capable of displacing not only the first and second elementaries, but also the ether particles, from the volume of which it experiences, during its gyration or flow, but little resisting pressure ; and if there is no pressure, it cannot be resisted and enclosed by them, but ranges freely among them into all space. Thus can they form no active space, unless such parts as can enclose them are present, prevent their excursive motions, and confine them within their own bounds. This can be done only among the air particles. Moreover, the surfaces which the active of the fifth finite describes in the course of its flow, almost equal in extent the air particle, the surface of which is also occupied by similar actives. In this manner also do fourth finites become active within the volume of air particles.

7. The space formed by the actives of the fifth finite in the

volume of the air particles cannot continue to subsist, unless it is continually supplied with a fresh quantity of actives; that is to say, unless the active space is continually supplied with fresh material. Otherwise the actives are immediately occupied by the first and second elementary particles, are converted into air particles, or pass into the surfaces of the surrounding air particles, and so perish and are dissipated. Similarly, the space formed by the actives of the fourth finite in the volume of ether particles cannot possibly subsist unless constantly supplied with fresh actives; otherwise they are immediately occupied by the first elementaries, and are converted into ether particles; or else, passing into the surfaces of the surrounding ether particles, they perish and are dissipated. Unless new actives perpetually entered the space, those already in the space, according to the theory explained in our preceding chapter, are either formed by the first and second elementaries into new air or ether particles, or else pass into the surrounding particles of air and their surfaces, and thus either way perish and are dissipated. That they are formed by the first and second elementaries into new surfaces if they are in abundance, we have above shown; but if they are not in abundance, by reason of their eccentric flow and gyrations, they are immediately transferred into every imaginable point of their space (part i., chap. vii., art. 12, 13), hence immediately into the boundaries; that is to say, into the volume of air particles, where they are absorbed. They can everywhere enter into the intervening spaces of the air particles, because these intervening spaces are large; particularly when the air particles are in a state of expansion (a subject on which we shall treat in the sequel); they can also pass into the surfaces of these particles, and, together with their like, have a common motion in these surfaces. If new air particles arise, the quantity of the particles is increased, and, together with this quantity, the motion of the volume, as we find indicated by the phenomena of wind. If the actives pass into the surfaces of the air particles, these surfaces may become larger, and consequently be in a more expanded state round about the space. If they become larger,

their volume becomes lighter; therefore the heavier particles tend in this direction, and consequently the volume of the surrounding atmosphere tends, as it were, to a condition of flame, more particularly if any part of the air particles which enter into the space be set free, and increase the number of actives; on this subject we shall speak in the sequel.

8. A large quantity of finites, or of the actives of the fifth finite, enter into the structure and texture of terrestrial bodies, such as vegetable, sulphurous, oily, and other substances; new actives may perpetually emanate and shoot forth from these into the active space; that is to say, if the bodies previously mentioned are in the very space itself. Numerous air particles also may enter the structure and texture of these bodies, and when these bodies are dissolved, these particles rush into active space. Air particles, in a state of separation from their volume and merged into active space, become immediately free. All the fifth finites occupying their surface thus become actives; in this manner fire may be abundantly fed by the air. A similar law obtains with regard to the actives of the fourth finite, occupying the surface of the ether particles. There are many evidences to show that fifth finites enter into the texture of terrestrial bodies, particularly of those which are of a finer and more open structure, such as animal, vegetable, oily, and sulphurous substances; for these appear and grow only on the surface of the earth, that is to say, where the air is, on the confines of the mineral and elementary kingdoms; if the plant is not supplied with air, some part of its nutrition is seen to be wanting. Even from vegetables and plants it is very evident that not only fifth finites but also that air itself has entered into their texture. for when submitted to the fire it escapes in large quantities in the form of flame, and presents the appearance of an expanded and active aura. The same phenomena are seen in the process of distillation; for when plants are either heated in a kettle or distilled, they are found to swell and give out an immense quantity of steam and air; and the same phenomenon is seen if either these or their juices be dipped into a corrosive fluid.

We may arrive at the same conclusion also a priori ; since the fifth finites are of such a nature that the hard parts of plants may be formed of them. On this subject, however, we shall treat more at large in our observations on the vegetable and mineral kingdoms. When, therefore, the structural connections of these bodies are broken up, the finites are afforded room to rush out ; and if they escape in large quantities, it follows that they become actives, and try to occupy space, so far as room is afforded them by the surrounding air ; and if the air particles themselves rush into this space, then, in consequence of the great energy of the actives, they not only undergo expansion, but also suffer a disruption of their surface, and thus the finites occupying the surface of these particles introduce themselves among the number of actives, and give increase and force to the space. Similarly, if the air particles, separated from the volume of their fellows become merged into a space as active, as we have described, they cannot but become completely tense ; and, when agitated by so many actives, suffer a disruption of their surface ; for they cannot be protected or defended by any of the neighbouring particles, but being in the highest state of motion, abandon their surface to the destroying operation of the actives. For unless their surfaces suffer compression on all sides and are in equilibrium between the forces, the structural connection of the surface ceases with its equilibrium ; because, as above stated, the air particle is pressed from within by the first and second elementaries, and from without not only by these elementaries, but by the ether, as also by the force of their own reciprocal weight. The same is true also even if there be no reciprocal weight pressure. Indeed, there would be none, should any particles separated from their volume float in the active space ; in which case also there would be no equilibrium of surface. Consequently, the particles enclosed within must act according to their force and nature, and keep the surface in a state of tension according to the equilibrium of the reacting forces. This they do the more when they are urged by the actives of the space to their highest motion, in which case they are reduced to a state

of still greater tension; they, therefore, can now no longer defend themselves; and thus with the entire loss of equilibrium there is an entire loss of connection in the parts constituting the surface. This will be still more evident in the sequel; that is, that the active space acts upon bodies not only in a simple but in a multiple ratio.

From the above observations it follows that air particles in a volume contiguous with others, or those in the boundaries of the active space, cannot be set free, or the parts of their surface cannot become active, unless they are separated from the volume of their particles and enter into spaces; which is the reason that flame is so copiously fed by the air, and its power and heat so considerably increased. In these processes we behold a type of nature ever repairing and renewing herself. Like the phœnix, she rises from her ashes; as often as she dies she comes again into life, and awakens from her funeral pile to a new resurrection. For the air undergoes a process of dissolution when entering into the structure of the parts of plants, and if these plants be submitted to the fire, the air returns again to its former state. Similarly if plants, boiled or rotting, undergo fermentation so that the more intimate parts of their structure are broken up, the air immediately regains the proportion abstracted, or the earth restores that which it had borrowed. Thus the operations of nature are carried on in a perpetual circle. In death she beholds life; in her funeral pile, her resurrection.

9. The air particles nearest the active space are in the highest degree of motion, and, consequently, in the highest and most rigid state of expansion. Such as are farther from the space are in a less degree of motion, also in a less degree of expansion and tension, and this according to their distance from the active space. Similarly, the active space cannot subsist unless the air particles are expanded according to their distance from it; that is to say, unless there be formed around the space a sphere of particles gradually less and less expanded and mobile. A similar law obtains with regard to the ether surrounding a space consisting of actives of the fourth finite. In chapters v. and

vii. of the present part, we have shown that both ether and air particles, during their greatest motion, are most highly and severely expanded. In the present case the air particles are expanded for a threefold reason; they are also agitated by their actives and excited to motion, and when thus excited the enclosed elementaries stretch the surface. The nearer also the air particles are to the space in which there are only the first and second elementaries, perhaps also some ether particles, the less are they in contact so as to be capable of undergoing pressure in every direction by their resting one upon another. A new supply of finites also takes possession of their surface, by means of which they can undergo greater expansion; hence near the active or igneous space they are in every respect more expanded than they are at a distance from it. From the equilibrium of the parts in motion, it is evident, however, that the active space cannot subsist unless there is formed a sphere of particles expanded more or less according to the distance from the space. One elementary particle is not movable by itself, for in moving it we cannot but move also the next particle, and the next again to this, and so on throughout the distance. For all the particles form one continuous expanse, and the motion of the parts is the motion of the whole volume; therefore the motion of one or more of the parts extends to those which are adjacent, a motion which can decrease only according to distance, and which must increase or decrease according as the motion of the parts is more or less rapid and local. The same is the case with regard to a volume of air surrounding its igneous space. By means of this sphere of air surrounding the igneous space, not only is the equilibrium in the air preserved, but also the space together with its actives is enabled to subsist; for the air particles thus have the greatest aptitude to receive the assailing impulsive force of the actives; and there is a certain similarity of action in the air particles and the actives of the space.

10. The air particles themselves, when excited to the highest degree of motion by means of the actives of their space, give rise to something similar to actives. They produce also something

fiery and warm. They also break up the structure of certain parts. Thus in their state of expansion and motion, the air particles resemble a kind of actives, although in one respect not so ; that is, they do not put the volume of ether particles into such motion as to diffuse light. Since not only the air but also the ether particles when expanded are thrown into a state of most intense central motion, it follows that these particles produce in their place an effect almost similar to that which actives produce in theirs ; the only difference being that the actives act by local motion and at every angle. They are present throughout all space in the ratio of their eccentric and excursive motion, and wherever they meet with an obstacle they turn it, try it, and act with impetus and weight upon its smaller structural connections. The ether and air particles, when in their central motion, act also upon structural connections similar to their own, and consequently produce a kind of heat or fire. Heat is thus a most intense central motion of the parts of air or ether ; the mechanism of the action and the breaking up of these parts I shall explain at large, when we have first ascertained the connections and structure of those parts from our theory of the mineral and vegetable kingdoms. The origin of heat of this kind is principally in the actives which are capable of putting the ether and air into motion, and also of so modifying the ethereal volume as to cause it to diffuse light, or to cause its contiguous expanse so to act at a distance upon this motion or effort as to reflect itself at every angle from any intervening object, and thus to render it visible to our organs.

11. Ether particles can be in the same space with the actives of the fifth finite ; but when they are in this space they are excited to a most intense motion ; and consequently in this state of motion have a high degree of expansion and rigidity. Ethereal particles thus contribute in a special manner to the amount and increase of heat. The actives of the fifth finite may in their space urge an ethereal volume into such great rapidity of motion, that this volume may give rise to modifications which have the appearance of light. The ether particles also

interiorly in this space may be disunited, and the space, thus increased by the actives of the fourth finite, rendered stronger and larger. Finally, the ether particles may at length be exterminated in some measure, as the active space increases in force and extent. That the ether can be in the same space with the actives of the fifth finite, and that the actives may nevertheless continue to perform their circles and rotations, follows principally from the dimensions of the two. The finites constituting the surface of the ether are of the fourth kind, and in these the point is raised to the fourth degree and power; so that if we consider the point as 1, there are then in the fourth finite 100,000,000 points, as we find by multiplying every dimension by 100. The fifth finite, however, in which the point is raised to the fifth power, possesses a mass 100 times larger, or one consisting of 10,000,000,000 points, being to the former in the ratio of 100 to 1. If, therefore, every particle of ether in the surface consisted of a hundred finites, the particle would not much exceed in mass the fifth finite rendered active, and this active may thus rotate within an ethereal volume, although not without experiencing some resistance. Fourth finites, however, when rendered active, remove from them the ether according to the principles we have laid down, and cannot gyrate within its volume, as we have above stated. Since, however, the actives of the fifth finite cannot but rotate their volumes among the particles of ether, by acting upon, soliciting them, and urging them hither and thither, in order to form a space to themselves; and since these particles, being exceedingly mobile, readily yield to actives thus in motion, it follows that the ether particles, according to our theory, when in the highest state of motion, must be in a state of very rigid expansion, and when expanded must give rise to a certain amount of heat and fire, particularly if there is any connection of parts upon which these particles can act in their own way; that is to say, both by a central motion and by expansion. The ether particles, therefore, in this state of motion and expansion must, to a considerable distance, bring the volume or contiguous expanse of their particles into a certain state of

motion, so that the ether may impinge upon the parts it meets, and which have a varied configuration, and by reflection and refraction present various modifications in the visual organs, which also contribute their own share in producing the effect. If the number of actives increases and the space is rendered still more strongly active, it follows that the ether particles possessing a less force of resistance are compelled both in place and space to give way; they also are partially broken up, particularly if they are very rare and begin to be separated from their contiguous expanse. If they are broken up, then not only a larger number of actives enter into the space, but also a stronger force (part i., chap. vii., art. 19); for the actives of the fourth finite can operate upon their own smaller connections both in virtue of their smaller mass and their greater velocity, as well also as the actives of the fifth finite.

12. The first and second elementaries can be in the same space with the actives of the fifth finite, and do not in any manner disturb their circles and gyrations, but yield to them just as the atmosphere yields to any weight, gyrating or revolving within its volume. For the first and second elementaries have a smaller dimension and are more yielding and elastic, being those in which the primitive elementary elasticity and capability of yielding are latent; there is nothing, therefore, to prevent these actives which are larger in mass from being in a state of fluency among them. The actives of the fifth finite are thus in a free state when introduced into the space where only the first and second elementaries are in a state of fluency. For in the surface of the first elementary there are second finites which may be in their ratio to fifth finites as 1 to 1,000,000. In the surface of the second elementary there are third finites, which in regard to their mass are in the ratio to fifth finites as 1 to 10,000, or even still more. Thus the ratio of the point to the first finite we have assumed for example's sake to be $\frac{1}{100}$, whereas it may be $\frac{1}{1000}$.

13. The force of the active space increases according to the number of the actives in the same space, and in proportion to the addition of the actives of the fourth finite to the number of

the other antecedent finites. On this subject the reader is referred to part i., chap. v., art. 22 ; chap. vii., art. 18, 19.

14. The space consisting of the actives of the fifth finite has no weight except what is imparted to it by the volume of first and second elementary ether particles forming the contiguous extense in this space. This space, moreover, has no determinate situation except that which is determined by the enclosed elementary ether particles, and by the air particles, which, having become lighter by their expansion, flow freely. On this subject see part i., chap. vii., art. 14, 15. There may be in this space in the meantime a volume of ether which has a definite position relatively to the particles of its own nature, which flow freely in the same contiguous space ; the space, therefore, may be affected in some measure according to the position of the ether, and according to the situation of the elements of the first and second finites, more particularly according to the surrounding air which encloses the space itself.

15. The actives of the fifth finite act by impulse upon the various objects they meet, and break up their connections. The ether particles also, which are in a state of intense motion, act upon them by their central gyrations and the activity resulting therefrom ; and also by means of their expansion. The space itself, too, by reason of its lightness acts upon the connections of the harder bodies, and breaks them up by reason of the equilibrium and amount of its pressure on both sides ; that is to say, both without and within the structure of the bodies. Numerous causes may thus assist in the disintegration of bodies by fire in an active space. That the actives of the fifth finite act by their weight and force, we have sufficiently shown above. For there are numerous connections between bodies, some of a more subtle, some of a grosser kind, which cannot be disintegrated by actives of the same kind ; grosser connections are disintegrated by grosser actives ; and more subtle connections, by actives that are more subtle. Consequently in a highly heated space the disintegration of the parts, so as to produce fluidity, requires the weight and force not only of actives

of the fifth finite but also of those of the fourth. What that is which is effected by actives we have explained in part i., chap. v., art. 10, 11.

Moreover, ether particles in their state of mobility and expansion act upon their connections, conjointly with the actives, both by their continual central movements without and within their structure, and by their lightness, acquired by the expansion of the ether and the expulsion of the air. For the ether particles that are enclosed in bodies tend to the same expansion, since they move toward a state of equilibrium; therefore by reason both of the tension and motion of these particles, the structure which is itself tense is broken up, and affords a passage to the enclosed particles to escape freely, and fill the space with fresh actives from the fifth finite; in the same way as air, when enclosed in a bladder or jar and distended by heat, bursts through the walls of the enclosure, and rushes with a blast through the fracture it has made. Numerous causes, therefore, occur before a body which has been completely disintegrated passes into a state of fluidity, or becomes converted into smoke, ashes, cinders, or flux, and before the parts which cohere by the more subtle connections, are divided and become finally separated.

Now inasmuch as the active space cannot subsist except by means of new actives, which perpetually enter into the space and so constitute it, it follows that it cannot subsist unless it is always replete with parts of the same kind, and which the previously mentioned actives supply by their disintegration; so that the space must consequently be crowded with sulphurous, oily, saline, vegetable, and other kinds of particles. For this reason the space can extend itself no further than the tide of these particles from which the actives come. Consequently, it also follows that this highly heated space may be rendered in its action stronger and weaker, in proportion to the number of these actives supplied by the parts floating in it. Not to mention other facts which are rather matters of detail than a part of the general law.

16. The space consisting solely of actives of the fourth finite and enclosed by the volume of ether, can pass through the atmosphere with a perfectly free current; it may, as it were, cleave through and penetrate even the hardest bodies; it may in its passage break up and disintegrate their more subtle connections, and give rise to more phenomena than the space formed by the actives of the fifth finite. For actives of the fourth finite can be enclosed only by a volume of ether particles, and consequently a space of this kind freely permeates the atmosphere and the interstices between its particles (for the air cannot retard its passage, because it is of greater dimension), and the moment it touches a particle of the air, it breaks up, and disintegrates its connection. It acts in the same way with other corpuscles and effluvia floating in the atmosphere, and also with whatever larger and harder bodies it meets with; moreover, the force of the space is increased and becomes more intense by the disintegration of the ether particles separated from its volume. It is for this reason that this kind of fire is called elementary, because, being generated in the form of lightning in the higher regions, it tends to the lower and carries with it material loosely formed of fourth finites; from which, as from a most subtle sulphurous substance, new actives pass out perpetually into the space. To describe more particularly the nature of this celestial fire and its marvellous effects, would be undertaking a task too tedious for the reader, although we might deduce them all in regular sequence from our principles. These are the fires that, according to the ancients, Jupiter grasped in his right hand and flashed out of his cavernous clouds; these are they which almost without contact penetrate the looser structure of bodies and leave them intact, while they break through and divide those that are finer and less obvious to the eye. Thus in the animal body, they lay open and disintegrate the hard and bony parts, but not those that are fibrous and fleshy. The subtle links uniting the soul to the body they more particularly lay open, preparing ways and passages by which the soul goes forth. The reason of the phenomena produced by this kind of fire every

one may learn for himself from the principles we have above explained.

17. It is of these fourth finites that the central globe of the earth consists; but they cannot burst forth and become active without being immediately laid hold of by the first elementaries, and converted into ether particles, according to the theory above laid down. If, however, there were a passage leading from the centre sufficiently open for these finites to escape through it. an active space would be formed by that part, at our present distance from the sun; and when formed it might continue to subsist so long as fresh finites constantly emanated and, as it were, germinated into the space. But by means of this space the sphere of the ether would considerably extend, and the earth lose that equilibrium which it now maintains at its present distance from the sun and in its present vortex; and, consequently, it would undergo some remarkable change not only in regard to its position and the orbit it describes in the vortex, but also in regard to its polar situation and axillary motion. I merely mention this as a corollary to our preceding propositions. It is possible that some such destiny may await our earth; and if so, it is one of which we can have no foreknowledge; neither can any one predict it, unless by indulging in such conjectures as would be calculated rather to excite ridicule than to be worthy of our graver thoughts.

18. By way of appendix we may here remark with regard to the actives of the sixth and seventh finites, that even these are possible, particularly since nature is enabled to ascend to higher degrees and powers of finiting and actuating itself. Let us suppose, therefore, the existence of finites or actives of the sixth finite, then from our principles it follows that they cannot be enclosed by the atmosphere, consequently that no space can be formed by them within the limits of any portion of our atmosphere, but that possibly they may be enclosed within a space by a volume of aqueous vapours. A space formed by the actives of the sixth finite would powerfully move the air, expand its particles, and thus induce a certain kind of heat,

as in the case of the actives of the fifth finite moving the ether.

The seventh finites, however, or the actives thence resulting, appear to be capable of forming no space within the elementary parts of our world, and could they exist collected together in any place, would make themselves known by some kind of noise in the atmosphere. They could never break up the connections of cohering parts, but would cause only a certain amount of contusion; and were any intelligent person present who knew how to connect them together so as to form a space and confine them within fixed limits, they would assume and represent all manner of Protean and Vertumnian figures and images. See part i., chap. v., art. 17. Let us, however, leave subjects of this kind, and pass on to the series of things existing in the world.

CHAPTER IX.

WATER, OR THE PURELY MATERIAL FINITE.

HITHERTO we have been pursuing the course of the earth through the vortical solar region, and have seen how at a certain distance from the place of its birth it became surrounded with an atmosphere. We may now contemplate the earth as still pursuing its course, as not having yet arrived at its final and destined orbit, but as constantly increasing its radial distance from the sun, from which it is receding diurnally and gradually. Every year the earth describes around its parent a revolution of short duration; every morning it salutes its parent anew, and every evening bids him farewell, for it is constantly measuring out days by a revolution upon its axis; thus it is perpetually meting out time by annual and daily revolutions. Its course being spiral, it is yearly and daily receding from the centre of its orbit; for by reason of its centrifugal force, it is ever hastening to its final orbit and fixed boundary; on which subject we shall treat in the following chapter. Now, as we are accompanying its course with a view to observe the changes through which it passes, let us mark in what manner it surrounds itself with water, and afterwards with a fertile crust of most varied aspect and abounding with entities of the most diversified kinds; a crust which, in a state of resolution, not only yields seeds, but develops them into different kinds of fruits and plants. Let us mark also how, after it has adorned its surface with the beauties of the garden and the field, man is finally introduced, as into some spacious apartment enriched with magnificent furniture. As yet the surface of the earth is naked, being surrounded only with ether and air; nor indeed can it receive any covering in closer proximity to its surface until it has travelled to a greater distance

from the sun, and until by means of successive gradations and vicissitudes it is enabled to produce upon itself various series, both successively and simultaneously. We now come to the subject of water. Our principles lead to the following results.

1. A particle of water is similar to a compressed particle of air, according to fig. 110 (p. 217), in which there remains nothing elementary, yielding, and elastic, but something hard, consisting of contiguous globules formed within another larger globule, according to the theory propounded in part iii., chap. v., art. 14, 19 ; chap. vii., art. 11. The particle of water is not a finite like one of the preceding finites, that is to say, capable of actuating itself, but is one which is purely material ; consequently water is not an elementary particle. In order that the connection and series of things successively arising, may be made the more evident and be the more clearly explained, we shall begin with the figure of the particle, from which it will be evident that it had its origin either simultaneously or successively with the air. This subject will be soon dealt with. At present we shall follow the successive steps of the series, and show how a particle of water is perfectly similar to a particle of air, or indeed is the same as a particle of air highly compressed. And because in this particle there is nothing elastic and yielding, for the enclosed elementaries are consumed in compounding the globule,—which in consequence of being interiorly deprived of its elastic elementary volume cannot be farther expanded, much less compressed, or be made to yield or to flow among the neighbouring particles in virtue of its own proper mobility and so to remain, in every state of motion, similarly and perpetually fluid,—and the consequence is, that the globule or particle cannot be called elementary.

With regard then to the origin of water, we may observe that water seems to have originated in the same manner as the air particles, but at an early period, and before the ether had attained its present altitude or amount ; as a result the new air particles were then larger, particularly in the vicinity of the sun, where all the parts, being circumfluent and occupying the surface,

possessed a high degree of motion and were subject to intense heat. At a distance, however, while the ether and air were still increasing in abundance, it seems that the particles of air which first arose with extremely large dimensions from the surrounding ether, must necessarily have become subject to more and more pressure from an increasingly higher column of similar particles until, when the degree of pressure had become exceedingly great, they lost their elementary nature and were converted into hard and resisting bodies. At a still greater distance from the sun, however, when the air was perpetually arising in the atmosphere of the enlarged ethereal regions, the air particles, it seems, could no longer retain the same dimensions; because, being subject to the highest degree of pressure, they were entirely occupied by the globules formed within. In the formation of these the first and second enclosed elementaries were consumed, so that scarcely any remained to restore the elasticity of the particle and to further expand it. Such was the origin of aqueous particles, deduced immediately from our first principles, so that they appear to belong to the same series as those of air. And because the origin of each is thus one and the same, the reader is referred, for our remaining observations on this subject, to our theory of the origin of air. The only difference between the two is, that in consequence of its larger surface, the aqueous particle at the surface of the earth is brought by the pressure of the increasing quantity of ether, and of the air which continually enters into it, into a state of equilibrium with the other particles; consequently, so large a portion of its extremely large surface is pressed inwards, as to be received by the enclosed elementaries and formed into new globules, which gradually press upon the particle and render it hard and resisting; thus urging and keeping it, in the ratio of its weight, near the surface of the earth. The figure of the particle may be seen in fig. 110 (p. 217), H, H, is the particle; and its parts, *n*, *n*, *n*, *n*, *n*. A shoreless ocean thus envelopes the earth, presenting the appearance of a universal waste of water.

2. Particles of water, or finites of this kind, cannot move

among one another like elementaries, unless there are interfluent elementaries to carry these particles with them, and thus set them in motion. The particles of water thus owe their motion and fluidity entirely to the interfluent ether. Aqueous particles are the more mobile and fluid, in proportion as the circumfluent ether particles are the more mobile, extended, and rigid; and the less mobile and fluid in proportion as the circumfluent ether particles are the less mobile, extended, and rigid, but soft, as it were. In proportion to the want of mobility and tension in the ether particles, the aqueous particles are torpid and languid, uniting and forming into a hard mass. That finites of this kind, or aqueous particles, owe their fluidity or mobility to the interfluent ether, which in its own nature is mobile because it is elementary, is evident a priori, or from the principles already laid down. For the particles of water do not possess an even and uniform surface, but one which by contact coheres with those which are in proximity to it. Neither do they possess a yielding elastic surface; for which reason they cannot reciprocally act upon one another by their force of elasticity and power of yielding, and thus become similar and uniform in every state of motion and pressure. Nor can one particle apply itself to another, like elementaries, which cannot become reciprocally fixed and bound together; but still, whatever motion they may possess, they are, solely by reason of their change in dimension (their figure being in other respects exactly preserved) enabled to maintain mobility. For when the ether is in its most mobile and rigid state, that is to say, when its temperature is highest, it renders water very highly mobile, and causes it to undulate and boil from the top to the bottom. The ether, moreover, circulates in water, forms itself into vapours, and under the appearance of air continually seeks the surface, and ejects itself in the same way as when steam carries a body upwards. Still in a perfectly quiet and calm state of the ether, when its particles from being soft, as it were, are unable to move the aqueous particles from one place to another or keep them separate, the aqueous particles must necessarily become confluent and attach

themselves to one another; while the ether itself in part escapes, inwardly forming partly into vapour, partly into larger particles, and by the solution of its soft and highly yielding surfaces, incloses itself like air, and variously occupies the spaces within, from which it cannot escape as long as it is between its own larger or else congealed vaporous surfaces of the water. This is evident a posteriori, because when there is no motion between the ether particles, the aqueous particles coalesce into a certain hard and material mass, from which they cannot be liberated except when the ether is urged into motion and a state of rigidity. The essentials, therefore, and the numerous elementary qualities which we have observed in the wave and current of our finites, we must not attribute to their own nature or virtue, but to the interfluent element. For instance, water exerts a pressure proportioned to its depth and also to the area; this pressure is exercised equally in all directions; the particles are put into modulated states and circular undulations; these undulations may be formed within the sphere of another undulation; not to mention many other particulars which we may see verified not only in other fluids, but also in every liquid and every volume of every hard and liquefied body. It appears then, that we cannot consider the aqueous particle as any other than a kind of hard body rendered fluid by an extremely small degree of heat; for there are some hard bodies which become liquid by a smaller, some by a larger and more intense degree of heat: water commonly yields to the smallest degree, which softens its rigidit and causes it to flow as a liquid.

3. The ether particles are capable of permeating the inter stices of water, but not those of the air, in consequence of their difference in dimension. The air particles are therefore in contact with the surface of the aqueous particles, and press upon them in proportion to the height or weight of their volume. From our theory of the origin of water, it is evident that the air particles are larger than the aqueous, and consequently cannot enter into the interstices between the latter, without forming spaces by collecting into a volume; hence it follows, in conformity with

common experience, that the air particles are in contact with the aqueous only as to the surface, and press upon them in a degree proportional to their height or weight of volume.

4. Many other facts remain to be noticed with regard to water; but inasmuch as its particles are not elementary, nor constitute any portion of the elementary kingdom, the proper place for noticing its phenomena will be where, God willing, we come to treat of minerals; for the aqueous volume is entirely similar to that of a mineral of any kind when melted into a volume, or liquefied. Our remarks on the subject of water would extend to great length were we to enter into all its phenomena. We should have to show, for instance, in what manner and for what reasons the connections of its particles could be resolved; in what manner after the dissolution the enclosed globules occupied the interstices between other and aqueous particles; in what manner, consequently, new terrestrial and saline parts originated; what were the figures of these parts, and the nature of their motions between the aqueous particles; in what manner these particles convey them through the fibres, stems, and pores of plants; how it is that they organise them into the plant form; how again they carry with them the superfluous parts in the plant into the external atmosphere; how it is that water hardens into ice and its vapour into snow, and how, as a result of this, forms like plants are produced; together with many other particulars pertaining to the material kingdom of nature, both vegetable and animal.

CHAPTER X.

AQUEOUS VAPOUR, OR THE FIFTH ELEMENT OF THE WORLD.

WE now come to vapour formed from water, the last product of the elements of our world, which, although the last, is yet, as an elementary, the first perceptible to sight and touch, for if a side view of the surface of hot water be taken, light globular vapours may be seen to rise, and the surface of the water to expand itself, and gradually pass in strata into a new kind of elementary product. Thus ultimate nature in forming her elements is where the senses begin; she is visible only in her terminations, and ends, as it were, where the knowledge of the senses first commences; and she renders herself visible to the human eye in order that man may not be ignorant of her qualities. The reason of this is, that the material perceives only by means of the elementary; for perception takes place only by means of motion in the elements. Our organs of sense are material and can perceive nothing except through the medium of the elements; consequently they perceive effects but not causes; the cause acts in order that the effects may be perceived; therefore, nothing elementary, that does not act upon any of our organs, seems capable of being sensated except what is ultimate, and which no longer acts upon our organs of sensation.

By this first visible elementary the theory of our principles is proved; for the senses now perceive certain particles rising fresh from the surface of hot water and flying upwards in masses into the atmosphere; they perceive that the origin of these particles is near the surface and not in the middle of the volume; that water suffers itself to be carried off in obedience to the motion of the elementary parts; that the particles thus rising are of a perfectly globular form, except when in their flight

to the higher parts they seem to assume more of an oval shape; that the ether set in motion by the sun or fire rolls them into these forms and occupies the space within, the watery particles taking the appearance of a surface or expanse, in the same manner as we have explained in regard to the orgin of ether and the air at the surface of the yet unfurnished earth; where in a similar way the parts next to its surface were raised up by the first elementaries into the ether and at the same time by the second elementaries into the air, the elements occupying the interiors of the particles and the finites their surface.

Thus the action of nature is similar to her action in small and large things. In the case of first and second elementaries, she acts in a manner similar to that of the third and fourth elementaries; where the fourth and fifth finites are concerned, her action is similar to that in the case of those of larger dimension, that is to say, she acts in the same way when air and ether are generated as when vapour is generated. Again, when vapour is generated, it can subsist among the circumfluent mobile and elementary particles, and preserve its sphericity in the same way as ether and air among their elementaries; this vapour is capable of expansion and compression just like the ether and air; in a word, in vapour we may contemplate, and perceive with the eye the whole mechanism and geometry of our elementaries. The fact that vapour subsists only for a few hours, days or weeks, arises from the changes to which the ether and air are subject; for the vaporous particle encloses ether, and must, therefore, undergo the same change as the ether; the air also flows around it, and, therefore, it must undergo the same change as the air; and since both the air and the ether in their higher regions are not self-identical according to the variation of their distances from the earth, it follows that the vapour which is carried to the higher regions is under the same law as the elements, which exert pressure partly from within and partly from without, or which constitute the particle itself. This is the reason, I say, why we now come to the ultimate of elementary nature and to the first object perceptible by the senses, and also why our

principles proceed by derivation from the first invisible and as yet ungeometrical simple, to the ultimate of the elementary kingdom, or the first visible product, the nature of which I now come briefly to explain.

1. Vapour is formed on the surface of water, and from the motion of the interfluent ether particles. Vapour when formed encloses within itself a small volume of ether; and externally is subject to the pressure of both the ether and air. The surface is thus kept in equilibrium by forces flowing without and within; and preserves its spherical form under every degree of pressure.

We have just spoken of the formation of vapour near the surface of the water, and in consequence of the parallelism which exists between the two we may transfer to our theory of vapour what we have already stated generally in our theory of elementary particles. As for instance, that they can originate only at the surface or limit of the extrafluent elementaries, where they are most highly mobile; can separate from others, and associate with the most highly mobile and can be put into motion with these, and, consequently, be formed into a superficial expanse, as is abundantly evident both from our principles and from experiment; for within their volume they cannot unfold themselves, since the neighbouring particles prevent them, and offer resistance in proportion to the height of the column. Since, therefore, ether particles are fluent in the interstices of water, they are hence rendered tenser and firmer, and, together with the others which externally press upon the surface of the water and tend to the same state of expansion or equilibrium, they must necessarily be enabled to dislodge the superficial particles, raise them to a certain extent, and combine with the rest to form an expanse; just as we see represented on a larger scale when water is placed over a fire, in which case multitudes of these particles project themselves from the bottom and escape in bubbles. Thus it is that aqueous particles are enclosed by ether particles, and that a particle is formed whose internal space is occupied by the ether; which, consequently, according to its nature exerts pressure in every direction upon the concave part

of the aqueous expanse, while the ether also together with the air exerts pressure upon its convex part. In this way these two elements occupy the intermediate surface, and equilibrate it in a state of compression in the same way as in a state of expansion; they always preserve it in a convex or similar spherical state, in the same way as we have above observed on the subject of the elementaries.

2. Vapour may be compressed and expanded; and it possesses a yielding and elastic surface; but owes all its elasticity to the enclosed ether, and the ether to its enclosed first elementaries. That vapour is therefore a particle not fully yielding and elastic, consequently, not perfectly elementary, but similar to an elementary, or endowed with elementary properties.

Inasmuch as its space is now occupied within by ether particles, and these, according to our theory, owe their elasticity to the first enclosed elementaries, it follows that vapour owes its elasticity and the yielding nature of its surface solely to the enclosed ether particles. And because in the first elementaries the elasticity is primitive, in the ether it is derivative, and in vapour it is derivative from the ether, it follows that vapour or steam is removed some degrees from the source of true elasticity, and possesses only the elasticity of the enclosed ether. Vapour may thus remain in its state of expansion, although subject to the pressure and weight of contiguous particles, provided the ether be in its state of rigid expansion; the vapour thus subject to the pressure of contiguous particles may collapse into itself and become compressed, provided the ether is not in a state of expansion or motion. It may thus undergo a variety of states of expansion and compression, and manifest phenomena according to the action of the enclosed and circumfluent elements. Although the vapour, therefore, possesses an elastic surface, it does not always yield to the compressing force, unless the enclosed ether itself also yields. It is not, consequently, under its own control, although it has in potency the force and functions of elasticity; consequently, it is not truly elementary, but may be said to be only becoming so. We have always presumed the

vaporous expanse to be contiguous. From these observations it follows that the surface of the vapour particle may be variously multiplied; that in its state of compression it consists of numerous foldings, series, and expanses; that in its state of expansion it consists of a smaller number, and thus that it may be expanded and compressed according to the state of the enclosed ether and surrounding air. On this subject the reader is referred to the theory of elementary particles explained in part i., and also in the present part.

3. A large volume of vapour may arise from a small volume of water, and this volume may become more and more expanded by the application of heat; indeed, it may be expanded with such great force and tension, that large weights may be raised, and walls of iron and brass burst asunder.

Chemists are well aware from experience that a small volume of water may produce a large volume of vapour, and that a continuous vaporous expanse may force its way through walls of brass and iron. Moreover, the workmen in foundries and smelting-houses have frequent opportunities of seeing heavy weights lifted by steam. For if small drops of water happen to have been enclosed in the stream of melted brass or iron, or are so situated beneath it as to be unable to escape without passing through, the whole mass of fluid will expand and bubble, projecting itself upward, scattering its molten fragments throughout the building. If the particles of the fluid metal with which the water is surrounded be so connected as not to give way, as we sometimes notice when scoriæ are flung into water, the water will nevertheless break the bonds, and, as from a sling, hurl the pieces with violence and a loud explosion.

Let us, however, revert to principles; for were I to illustrate them fully with experimental facts, I should require to fill volumes. Every distinct element, when submitted to examination, has its own distinctive volume. The case is the same with our present theory of vapour. Still, however, I desire to show that vaporous particles, when forming a united expanse, possess the same force and quality as air and other elements. Vapour

expands, for instance, on the application of heat, and distends any coercive bonds just as air distends bladders. It is, therefore, evident that every particle of vapour is similar to an elementary, which is capable of being expanded and compressed, of flowing in association with particles near to it, and of subsisting in the highest degree of motion. Neither can it be forced out of its spherical form by any weight or incumbent mass. It can also exert pressure equally in all directions ; in a word, it is perfectly similar to its progenitors, the air and ether. We cannot doubt, therefore, that the elementaries previously referred to are subject to the same mechanism as the new particle endowed with elementary properties. From its parallelism with the elements, it therefore follows that any particles of vapour forming a united expanse are capable of the highest degree of expansion ; that the expansion may gradually increase if a constant stream of water is furnished from which new particles of vapour may not only arise and pass into the expanse, but pass from one vapour to another in one continuous stream, ascending from the bottom to the top, and thus may afford room and sufficient means for still greater expansion. And if any portion of these particles bursts as the result of too great an expansion, the water hence arising and passing into the surfaces of the neighbouring particles, always provides them with fresh means for further expansion.

4. Particles of vapour differ from bubbles of water in this respect, that interiorly the former contain only ether, while the bubbles contain both ether and air.

In these particles of vapour we may see a still further product of elementary nature ; since not only the ether but also the air encloses itself in an aqueous surface. As these phenomena can be seen by the eye I need not any longer dwell on the subject.

5. Finally, before leaving our theory of elementaries, I would wish to explain in a few words the connection extending, according to our principles, from the first simple down to a bubble of water. I would observe then that in every bubble of water there is contained all that had previously existed from the first simple ;

every kind of finites, actives, and elementaries, of which we have treated in the course of our present work; so that in a small bubble the whole of our visible and invisible world is latent. We have thus the macrocosm in the microcosm; the world in a particle; the whole of our *Principia* in a nutshell. Nature is the same in the greatest things as she is in the least; in the whole as in the part. In the minutest things we behold the principles of nature's mightiest operations. For we see in a bubble of water the fifth element or vapour, the aqueous surface, for instance, with enclosed ether; we have also air or the fourth element of the world enclosed, as we learn from the preceding article; around the air we have the ether, or the third element; around the ether, and in every particle of the air we have the second element; around the second, elementaries, as also in the air and the ether, we have the first element; thus we have all the elements both without and within the structure and surface of the ether, and these all again enclosed within a bubble of water. The case is similar with regard to the finites; the simple or the point is latent in the composition of the first finite; the first finite in that of the second; the second in that of the third, and in the surface of the first elementary particle; the third finite in the composition of the fourth, as also in the surface of the second elementary particle; the fourth finite in the composition of the fifth, and in the surface of the ether particle; the fifth finite in the surface of the particle of air; the material finite or water in the surface of the bubble; thus have all our finites made their entry into a bubble of water in regular order. Again, in regard to the actives, the active of the first finite is latent in the first as also in the second elementary particle; the active of the second finite in the second elementary particle; the actives of the third, fourth, and fifth finite, in the surface of the second elementary particle, the ether, and the air. These actives also are one and the same with finites, which, in a free state, according to our theory, exist as actives.

The nature of the connection of the elements with one another is evident from the fact that the first element surrounds and

presses the second; the second surrounds and presses the third; the third surrounds and presses the fourth; the fourth surrounds and presses the fifth; thus do all the elements from the first to the last form together one continuous expanse; one therefore maintains a relation to another, and thus ends are connected by intermediates; the last with the intermediate, the intermediate with the simple; or what amounts to the same, the ultimate end is connected with the simple; and these are the more perfectly connected in proportion as the connecting elementary parts are in their natural state of motion and freedom. Whatever befalls one is immediately communicated from it through the intermediates to the ultimate. The smallest vibration in any part of the surface of our bubble communicates immediately an entire vibration to the surface of the enclosed air; the vibration of the air communicates an undulation to the ether; the undulation of the ether communicates a certain local motion to the second element; this motion of the second element impresses a considerable local motion upon the first element; consequently, the least motion in a grosser element causes a considerable motion in the finest, and in this way motion is spread from one extremity to another by reason of the general contiguity of all the elements, and the special contiguity of each in itself. Thus the thread of our principles extends from the simple to the ultimate without a single broken link; and we may therefore see how from one and the same force and cause all things derive their origin.

CHAPTER XI.

THE VORTEX SURROUNDING THE EARTH, AND THE EARTH'S PROGRESSION FROM THE SUN TO THE CIRCLE OF ITS ORBIT.

BEFORE proceeding to the consideration of the things more immediately pertaining to the earth and to the hard crust which surrounds our globe, we will briefly refer to the laws according to which it pursues its course from the sun to the orbit which it describes at the present day and which it renews every year. From what we have already stated, it is evident that the earth had already travelled a considerable distance from the sun; that as soon as it began its course freely through the vortical region, it began to rotate on its axis and revolve round the sun; that at first it described only small circles, then gradually larger ones according as it reached a greater distance from the sun. At first the years were only of short duration, indeed it could comprise a whole age within the limits of our present year. In the course of time the duration of its years was gradually extended until they finally reached their present limit, beyond which they cannot go so long as the state of the solar vortex and the earth's rotation on its axis continue as they are. Now since the earth, in its passage from the centre or sun, described spiral orbits, it may be well to become acquainted with the laws of its progression and periods, or the rate of velocity with which it pursued so extended a course. That our argument may observe a regular order, we shall first remark briefly on the vortex of the sun and of our earth.

1. In the solar vortex formed by the spiral motion of the elements from the centre to the circumferences, the elementary particles are not only reduced to a regular arrangement and motion, but are perennially kept in this by the constant action

of the sun in the middle of the vortex. Consequently, there is in this vortex a force or tendency from the centre and to the centre, according as the bodies are lighter or heavier than the volume of the element.

In our first and second parts we have abundantly shown that the first and second elementaries can move only in a spiral and vortical direction; that they cannot, for instance, be put into any other motion than such as accords with their mechanism and figure; that they are then in their truest and most natural position when they assume a vortical arrangement; that they spontaneously and wholly tend to this motion; that they so dispose themselves as to adapt even their very figure to their distance and motion, or that when compressed they tend to a more rapid gyration than when dilated, more rapid at a smaller distance from the sun than at a larger; that they cannot be at rest except in the absence of a centre around which they can gyrate; that the perpetual active vivifies, renews, and, as it were, preserves the perennial action of the particles of the element; not to mention other particulars of which we have spoken above.

If such, then, is the natural arrangements of the parts, and if their motion is spiral, it follows that bodies forming a volume of this kind tend either to or from a centre; for the current of motion itself forms continuous spires from a centre to given circumferences; the geometry of the parts is similar; but, adapted from the centre to the circumferences by compression and expansion, a very heavy or light body in a stream of this kind is carried in the direction of the moving parts; for while it is among the parts that are in motion it cannot be at rest but must follow in the current. If the body is too heavy to follow in the exact spiral course of the current, it yet continues to be driven by a certain force from a centre or to a centre; for all spiral motion tends to some further limits and to circumferences of some kind; if the body does not travel along all the innumerable spires described by the parts, still it travels along a few; or if not a few, still at least one; or if not one, still it pursues the course of the diameter; for a spiral motion is in the direction

both of circles and diameters. If a hard body cannot follow in the course of the circle, it follows in that of the diameter; the various spirals are acting continuously one after another, each adding its own motion, thus urging the body by a force most highly mechanical in a vertical direction or directly along the diameter, and forcing it on by its convolutions in a manner not unlike that in which a screw raises weights; so that by adding step to step and one force to another, the body is driven progressively onward. It is for this reason that in the solar vortex there is a centripetal and centrifugal force.

2. The earth continually revolves round its axis like a large finite, and spontaneously; that is to say, by reason of the effort of the individual parts constituting its central globe; and thus it begins to measure out the intervals of day and night at the moment of passing from the sun. From this moment also it appears to perform its axillary revolutions more rapidly than it does at a greater distance from the sun, when a considerable portion of it is consumed in the formation of ether, air, water, and terrestrial matter, and the parts of the earth become more closely bound and connected with one another by means of an incrustation consisting of different bodies.

Since, according to our theory, the earth consisted at its beginning only of finites of the fourth kind, and these finites were of such a character as always to tend to become actives; since according to the principles in parts i. and iii., these finites put their compound finite not only into a progressive but also into an axillary motion; and since in her motor relations nature is identical with herself both in her greatest and least operations, the axillary motion of this large finite arises from that of her smaller finites, and has its origin at the same moment that it issues from its parent. At first its motion is more rapid, since it consists of a larger combination of individual parts, and before any portion has been consumed in the formation of ether, air, water, hard and earthy crust; at this period its individual parts are not held so fast and so restrained within their limits, but that, in accordance with the force they exercise, the earth can move freely.

3. The earth, like a large active, has a tendency to a second motion, or from circles round the sun, by means of which it forms a surface not unlike the previously named actives; still, however, it was carried round the sun principally by the stream of the solar vortex. Hence from the beginning of its journey it was perpetually meting out, by its circular and periodic revolutions, winter and summer, spring and autumn, that is to say, years, but of less duration than those of the present day.

This large finite, or the earth, when in a free state could not but actuate itself, according to the theory of actives in part i., and the theory of fire in our present part. At the commencement of its diurnal revolution, therefore, it immediately began to divide out its years into summer, autumn, and the other seasons, but since it then had a greater velocity, and since there was then nothing to impede or hinder the free motion of its individual parts; since also its periodic revolutions were more restricted and were described more rapidly round the sun, it follows that both the years and the seasons were shorter in proportion to the greater proximity of the earth to the sun.

4. The earth, moving among the elementary particles of the solar vortex according to its magnitude and the velocity of its motion, formed a vortex around itself, just like the small magnetic corpuscle treated of in part ii.; consequently at the commencement of its journey it described first a larger, then afterwards a smaller vortex. See part ii., chap. i.

It is a law of mechanics, that a body moved rapidly describes a larger vortex than a body moved slowly; it is also a law of mechanics, that a larger body describes a larger vortex than a smaller; the greater the mass and velocity the greater the momentum or weight; for the momentum and weight are compounded of the mass multiplied into the velocity. Hence a larger and heavier body in motion possesses a greater momentum than a lighter body, or a body with less motion. If a similar or greater degree of velocity be communicated to a body of larger mass, it has a greater momentum for circulating the elementaries, which on their part also spontaneously follow in its

course, having the greatest possible tendency to motion. We therefore see a greater and smaller vortex of the particles of the first and second element, formed in proportion as the mass in motion is greater, and in proportion as there is a greater motion in the mass. It therefore follows, that the earth, when thus in the centre of its vortex, was in its natural position; that it could not travel beyond its vortex, nor move unaccompanied by the vortex; but that so long as its axillary motion remained, so long also the vortical motion of its parts remained, always determined and proportioned to the size and velocity of its body.

5. The vortex formed round the earth aimed at an equilibrium in the solar vortex, that is to say, it occupied the place where it could be in a state of equilibrium. Were the vortical motion more rapid, it would seek a different place from what it would were the motion slower.

A smaller vortex formed in a larger separates itself, as it were, from the larger by reason of its motion; for the elementary particles which are at a distance from the centre of the larger vortex cannot thus dispose themselves into the motion and position of the particles in this vortex, because they now revolve around another centre; consequently, within the smaller vortex they are in a different state of expansion and compression. Those, therefore, which flow outside the vortex are either more expanded or more compressed; consequently the volume which is in vortical motion and rendered lighter or heavier, can subsist only at that distance from the centre where it finds an equilibrium of weight; just as we perceive lighter volumes rising in the atmosphere ascend to some higher and given region, and take their place at that given height in which an atmospheric volume of equal bulk is of the same weight; that is to say, in which the two balance each other. The smaller vortex, therefore, seeks a state of equilibrium at a greater or less distance from the centre of the larger vortex, or among its elementary particles more or less compressed.

This, however, did not prevent the elements of the solar vortex from exercising a pressure within the minor vortex also, in pro-

portion to their altitude, and similarly in every direction. Nor did it prevent them from exercising this pressure, if smaller vortices were formed within the larger; whence from the general pressure of the solar vortex there arose a tendency to the centre of the earth. This might be proved by a variety of facts, as well as from known geometrical principles. Smaller circles described in water, the ether, and the air do not prevent a large one from operating in any direction conformably to its own mechanism. A volume in the highest degree of motion, whether it be one of water or air, does not prevent the existence of a pressure according to its height or column, and this even in the most rapid torrent. The expansion of the air produced by the most intense fire does not prevent the air from being superincumbent and pressing upon the volume beneath it; nor does it prevent the mercury in the barometer from attaining to its exact height, although the air within the expanded volume be rarefied to such a degree as to form an equilibrium of expansion. Not to mention other particulars, which we shall reserve for our observations especially devoted to this subject.

6. The greatest motion of the solar vortex was at the centre, and became gradually less as it approached the circumferences, so that it was least or none in the farthest circumference, and this too in the plane of its zodiac.

For if the sun is the source of motion, and if this motion spreads from the sun spirally toward the circumferences, so that one particle moves another onward, it follows that where the first motion is, there also is the greatest; that the operating cause is stronger than the effect, and is gradually weakened by a certain resistance of the distant parts; consequently we see that in the solar vortex the planets that are nearer the sun revolve with greater velocity than those that are more remote. That the motion takes place in the plane of the zodiac, may be seen in part i., chap. vi., and various other places.

7. The earth, which was compelled to describe innumerable spiral circles in its passage round the sun, travelled with a velocity gradually diminishing in proportion to its distance from the sun.

Its motion also decreased according to the circles it described, or its annual revolutions in a simple ratio ; but in relation to the diameter or right line drawn perpendicularly to the sun, in a duplicate ratio.

In the spiral orbit described by the earth, the diminution of its motion could be no other than in a simple ratio, because it arose only from the resistance of the fluent particles ; and since of these particles there was a successive series extending spirally from the centre to the circumferences, the motion was every moment retarded by this series at every successive step ; and because the cause of retardation and resistance was simple, the ratio of velocity was consequently simple. So that in a simple ratio, according to the spiral circles, the greatest velocity is in the centre, a less degree in the circumferences, and the least in the ultimate circumference. Hence at every step of the progression in the circumferences the velocity becomes less ; less for instance in *b* than in *h* (fig. i., vol. i., p. 118), less in *h* than in *i*, less in *i* than in *k*, least in *d*, and none in *e* or *g*, which is the simple ratio of the lengths from one point in the arc to another. Since all resistance arises from the series of particles flowing into the same figure ; and since this resistance can be considered only according to the figure into which the series of particles flow, it follows according to the figure that the ratio of the velocity is simple, but not so according to the diameter from *a* through *bc* to *d*. Now since the fluxion is spiral, and every moment is directly receding from its centre more and more along the radius or diameter, there arises hence another ratio which we have to consider both in the spiral series and at every distance from the centre ; consequently now that we have the accession of another ratio, we have, according to the general rule, a duplicate ratio from the centre to the circumference, or a ratio according to the diameter, from *a*, *b*, *c* to *d*. Thus when a body falls through any medium, if there be added every moment to the natural simple arithmetical value of its motion a constantly similar degree of velocity, there hence arises a duplicate velocity, or the ratio which simple ratios have to their squares. The earth

therefore, as regards its recession along a diametrical line, seems to diminish its velocity in a duplicate ratio.

8. With regard to the velocities in the solar vortex at the several distances from the centre, they are in the diameter in the subduplicate ratio of the distances from the ultimate periphery, or that in which all the motion ceases. In order, therefore, to obtain the velocity of the vortex moving in any circle, and, consequently, the velocity of a planet or earth moving in this circle and round its own centre, it is to be remembered that this velocity is in the subduplicate ratio of the distances from their ultimate periphery. Let the distance from the ultimate periphery $bc = d$, the velocity $= v$; then, according to the common rule, $d : \mathrm{D} :: v^2 : \mathrm{V}^2$; that is to say, the velocities are in the subduplicate ratio of the distances from the ultimate periphery. Or if the whole distance or radius extending to the centre $= x$, and the radius of the given distance be $x - d = r$, there will arise this proportion; $x - r : x - \mathrm{R} :: v^2 : \mathrm{V}^2$, or the velocities are in the subduplicate ratio of the differences of the radii.[1] Similarly in the solar vortex, the times are [inversely] in the subduplicate ratio of the distances from the ultimate periphery to the centre; for, according to the common rule, the times are [inversely] as the velocities. If, however, the vortex be such that the least motion is in the centre, and the greater in the direction of the circumferences, then the velocities and [reciprocals of the] times will be in the subduplicate ratio of the radii from the centre.[2]

9. If two planetary bodies be in motion in the solar vortex, each at a different distance from the centre, but moving in a circle or ellipse round the sun, the squares of the periodic times of each body will be as the squares of the radii divided by the

[1] True only if $\mathrm{R} : r :: d : \mathrm{D} :: x - r : x - \mathrm{R}$, or for the author's "middle" position (see bottom p. 277).—*Trs.*

[2] The velocities acquired in a given time under uniform acceleration by a freely falling body without initial motion are proportional to the times; but just as in the chapter on the second finite, where the argument starts (vol. i., p. 125) with the proviso: "If the body revolves round a centre," by "times" are meant times of periodic revolution, as is repeatedly stated (pp. 127, 128, vol. i.), so here, it is not the times of free fall, but of revolution which are meant, since the author is speaking of "the velocity of a planet or earth moving in this circle." Hence the need of these parenthetical emendations.—*Trs.*

distances or complements of the radii extending to the ultimate periphery.

In fig. 1 (vol. i., p. 118), let $dc=d$, or the distance from the ultimate periphery. Let $ac=r$, or the radius of the same circle. Let $db=\mathrm{D}$, or the distance of either planetary body from the ultimate periphery. Let $ba=\mathrm{R}$, or the radius proceeding from the centre. Let $da=x$, or the whole radius from the centre to the ultimate circumference. Then the squares of the periodic times of the circle c are to the squares of the periodic times of the circle b, as $\frac{r^2}{d}$ to $\frac{\mathrm{R}^2}{\mathrm{D}}$; or what is the same, $t^2 : \mathrm{T}^2 :: \mathrm{D}r^2 : d\mathrm{R}^2$.[1] The reason is, that the velocities at c and b in the figure are according to the general rule thus obtained, $d : \mathrm{D} :: v^2 : \mathrm{V}^2$, or $\mathrm{D}v^2 = d\mathrm{V}^2$. Therefore $v=\mathrm{V}\sqrt{\frac{d}{\mathrm{D}}}$, or the velocity in the circle c; and again, $\mathrm{V}=v\sqrt{\frac{\mathrm{D}}{d}}$ or the velocity in the circle b. If this velocity be divided into the periphery of the circle, we then have the periodic times. Instead of the peripheries or circles let us take the radii, because these are similar to, or are in the same ratio with, their circles. In this case $ac=r$; and r divided by $\mathrm{V}\sqrt{\frac{d}{\mathrm{D}}}=\frac{r}{\mathrm{V}}\sqrt{\frac{\mathrm{D}}{d}}$; which is the periodic time of the circle c. The periodic time of the circle $b=\frac{\mathrm{R}}{v}\sqrt{\frac{d}{\mathrm{D}}}$. Now instead of v, or the velocity of one circle, let us take its representative $\sqrt{d}$, and instead of V let us take its representative $\sqrt{\mathrm{D}}$; we have then the periodic times thus, $\frac{r}{\sqrt{d}}$ and $\frac{\mathrm{R}}{\sqrt{\mathrm{D}}}$; and squaring these we have $\frac{r^2}{d}$ and $\frac{\mathrm{R}^2}{\mathrm{D}}$; therefore $t^2 : \mathrm{T}^2 :: \frac{r^2}{d} : \frac{\mathrm{R}^2}{\mathrm{D}}$, according to our proposition.

If, however, the vortex be so formed that its least motion is in the centre, and its greatest at the peripheries, then the squares

[1] This requires that $r=1/d$ and $\mathrm{R}=1/\mathrm{D}$, if Kepler's harmonic law is to be fulfilled. In regard to the introduction of a distance from an "ultimate periphery," see Appendix A, p. 625.—*Trs.*

of the periodic times will be as the cubes of the distances from the centre; or $t^2 : T^2 :: r^3 : R^3$ [1]

On a further consideration of the subject, however, we shall find there will be a considerable difference, if the two planetary bodies vary their distance from the middle respectively, or in the middle of the vortex.[2] If each body is not far distant from the middle of the vortex, or if in the two circles they are almost equally distant from the middle, then there is not much difference between them; D will be almost the same with r. or $D = r$ nearly. Similarly $d = R$ nearly; and in this case, or in the middle of the vortex, or else on each side equally from the middle, if instead of D we put r, and instead of d we put R, we shall have the forementioned ratio of $t^2 : T^2 :: r^3 : R^3$, or the squares of the periodical times are as the cubes of the distances from the centre.

10. Two planetary bodies moving at unequal distances from the sun or centre, differ in their velocities; these velocities are proportional directly to the radii and inversely to the times. For if $t^2 : T^2 :: \frac{r^2}{d} : \frac{R^2}{D}$, and if instead of d we substitute v^2, or the velocity which is its representative, it follows that $t^2 : T^2 :: \frac{r^2}{v^2} : \frac{R^2}{V^2}$, or what is the same, $v : V :: Tr : tR$, according to our rule.[3]

If, however, the motion increases from the centre to the circumference, then the velocities will be in the inverse subduplicate ratio of the radii, or $r : R :: V^2 : v^2$.[4]

In this case, however, if the two planetary bodies are not far distant from the middle of the vortex, or if they are almost equally distant from the middle of the vortex, namely, one on one side of the middle and another on the other side, then the calculation for each almost coincides, so that d is almost equal

[1] This should be $t^2 : T^2 :: r : R$. See Appendix A, p. 624, where the argument of page 128, vol. i., is discussed.—*Trs.*

[2] By the "middle of the vortex" is evidently meant a point halfway from the centre to the "ultimate circumference."—*Trs.*

[3] This follows from the fact that $v = \frac{2\pi r}{t}$ and $V = \frac{2\pi R}{T}$; but the initial proposition is subject to the same proviso as in no. 9.—*Trs.*

[4] The proportion, as stated, expresses the fact for the solar system, but should read $r : R :: v^2 : V^2$ to be consistent with the definition.—*Trs.*

to R, and D to r; hence whether we make use of the former or latter in our proportion, the result will be almost the same. In case however the distances from the middle differ much from each other, the result will be proportionally different.

11. If two planetary bodies gyrate at unequal distances from the solar centre, the centripetal forces are as the distances from the ultimate periphery divided by the radii.

If c be the centripetal force, then according to our rule $c : C :: \frac{d}{r} : \frac{D}{R}$ or, $c : C :: dR : Dr$. The reason is, that the velocity at the first distance from the ultimate periphery d (viz. in the circle c) is thus obtained; $d : D :: v^2 : V^2$; or $Dv^2 = dV^2$, and $v^2 = \frac{dV^2}{D}$ and $v = V\sqrt{\frac{d}{D}}$. The intermediate velocity is a mean proportional between the radius and centripetal force: let this radius $= r$; then $r : V\sqrt{\frac{d}{D}} :: V\sqrt{\frac{d}{D}} : c$, or $\frac{dV^2}{D} = c\,r$. Since V^2 is similar to D, and may be substituted for it, we have $\frac{D}{R} = C$, etc.; whence $c : C :: \frac{d}{r} : \frac{D}{R}$, according to our proposition.

In the vortex, however, whose motion is less at the centre and greatest at the circumferences, the centripetal forces are inversely as the squares of the radii, that is to say, $c : C :: R^2 : r^2$.[1]

In the middle of the vortex, or at equal distances from the middle, there cannot be much difference between d and R, and between D and r, hence the proportion into which each enters agrees with the other.

Since it may be shown not only a priori or from principles, but also a posteriori and from experimental fact, that bodies moving in the solar vortex perform more rapid revolutions in the peripheries nearer to the centre than in those which are more remote from it, I may venture with some degree of confidence to apply the foregoing analogies to the earth and the planets.

[1] This should read $c : C :: \frac{v^2}{r} : \frac{V^2}{R}$, irrespective of hypotheses.—*Trs.*

CHAPTER XII.

THE PARADISE FORMED UPON OUR EARTH, AND THE FIRST MAN.

We have thus briefly described the way in which our earth surrounded itself with ether, then with air, and lastly with water; we have shown that as soon as it began its journey, it revolved on its axis, and also at once round the sun; and that from its infancy, therefore, it began to measure out years and days. We have explained how its revolutions were at the beginning more rapid, then in process of time slower, till, in arriving at the orbit it now annually describes, it attained its slowest motion. Here we left it, surrounded with water without a shore. Not, however, to leave it to the lawless fury of a flood, we here resume the subject, and explain in a few words in what manner shores were now added; that is to say, how it was that dry land was acquired; how the waters superinduced upon themselves a crust, which not only coerced them within given limits and kept them within an enclosure, but also how all that we now find in the vegetable and mineral worlds was enabled to enter into the crust; how heaven also not only deposited its seeds in this crust, but also gave them germination and expansion. This, however, we shall explain but briefly, since the subject is one which strictly belongs to a treatise on the mineral and vegetable kingdoms. Not to forsake the earth then in its state of inundation, we shall next in order briefly enquire into the origin of the mineral kingdom. With respect, therefore, to the incrustation we have mentioned, it is to be observed:—

1. That this crust was formed upon the water by the dissolution of the parts in the water, and the interjection of finites which emerged to the surface, and formed upon the water a crust

which continually increased by an addition of parts one under another.

It would be a tedious task to explain everything relating to the origin of hard bodies composing the terrestrial crust from its bottom to its surface ; we may, however, observe thus much in general, before treating of the mineral kingdom,—that from the operations of causes very diversified, as also at various distances from the sun ; from the immense variety of changes which the earth underwent in its journey from the sun, first at a more rapid, then at a slower rate, first in the immediate presence of the sun and under its rays, then at a remoter distance ; that portion of water which was of looser texture, and the parts of which had from various causes been set free, occupied the interstices of the other portions of water, and so together with these emerged to the surface, accompanied by fourth and fifth finites which mingled themselves with them. From these arose compound entities of different forms, which produced a crust, as also other entities flowing freely, because adapted to the interstices of the water, and giving rise to a variety of phenomena. On this subject, however, we have here said sufficient.

2. The earth underwent innumerable changes before arriving at its present circle or orbit, that is to say, changes as numerous as the circles it completed, or the different distances of these circles from the sun ; as numerous also as were the degrees of velocity in the course of its annual and diurnal revolution ; in a word, every day and hour it underwent some new change, during its journey from the sun to its present orbit.

The number of changes it experienced, therefore, may be concluded from this, that when issuing from its chaotic state it was at first naked, and was so near the sun as to appear comparatively diminutive, yet able to look closely into the vast solar ocean ; that afterwards every hour, day, and year it receded to a farther distance, and in relation to the immense solar disk became smaller and smaller, because subtending a continually less angle ; that it thus was in a less degree bathed in the solar rays. The farther it receded the less became its relative size, and the greater

was the difference of manner in which the solar beam was received on its surface. Every moment it was changing its place and its distance from the sun; so that the sun could act upon it when it was near in a manner different from what was possible when it was farther off, and with variety, every successive moment. Thus every instant it was undergoing some change in its relation to the sun, which was, as it were, ever changing, producing, and vivifying everything in its vortex. Similarly it was ever undergoing some change as to the elementaries flowing round it, which near the solar centre are subject to a greater degree of compression and a more rapid motion than when farther from it; so that what in the first instance these elementaries united, they at other distances either dissolved or united in a different manner, and the contrary.

The changes the earth experienced are evident also from these further considerations; that it was at first entirely uncovered, then after this enveloped with ether, and in this state received the solar heat in a different manner from what it did before, and in a manner again continually differing in proportion as the sphere of the ether became larger and larger; that it afterwards became enveloped with air, the column of which grew continually higher, and thus was capable of being set in motion in a different manner when it was low from what it could when it was high, and in ways differing from each other at different distances from the sun. When finally it was surrounded with water, it then assumed a still different state, and in this state also received the rays of the sun in various ways, differing according to its distance from the sun. Its states were also varied first by its more rapid, and afterwards by its slower revolutions on its own axis; by its completion of longer and shorter years, which varied according to the variation of its motion, and, consequently, according to the temperature of the newly-formed ether, air, and water, or to the seasons, so that the earth must necessarily have undergone a variety of new changes. To this we may add, that at every new distance its ecliptic was different, its equator being exposed to the sun in one place more directly, in another more obliquely,

just as we see in planets nearer to the sun and farther from it; in which cases different zodiacs are traced, according as the different solar or proximate vortices more or less alter the direction of the axis; in this case, therefore, the seasons of the year must have been constantly dissimilar, such as the winters, summers, springs, and autumns; the frigid zones also could not always have been frigid. In a word, it is impossible to enumerate the various changes which the earth must have necessarily experienced before it had reached its final destination. From all these considerations, however, we are at liberty to infer that the system of our earth must have undergone innumerable changes before it could have been fully completed, and have consisted of so many series of things simultaneously and successively arising; or before it could have been enriched with so many things as would suffice to supply the mineral, vegetable, and animal kingdoms; before also it could have received its seeds, unfolded and expanded them, and so delightfully and variously adorned its own surface.

3. During that state of the earth in which its revolutions round the sun and its rotations upon its own axis were more rapidly performed, or when the earth measured out shorter days and years, the whole surface of the earth enjoyed perpetual spring—a season the most highly suited to the purposes of generation and procreation. Without this perpetual spring no seeds would have germinated, nor could the various subjects of the animal and vegetable kingdoms have been produced.

That our earth formerly measured out days and years of shorter duration than the present seems to be confirmed by the age of our first ancestors; for we learn from Scripture that the lives of some extended to eight or nine ages, or that they lived to see ten and even thirteen generations of their own families, and that it was but a slight thing for them to live from one to three ages. If, however, the earth at that time performed its annual revolutions more rapidly, and if it measured out a year to its inhabitants within the space of a few of our present months, they might in this case have lived through several ages, when yet

the duration of these ages, or the greater number of birthdays occurring in one life, might not much have exceeded in duration a single age in the present day; whence they might be said rather to have lived a great number of years than to a great age: for if they could have reckoned as many summers as the inhabitants of Mercury or Venus, the number of their years would be greater than ours, but the duration itself equal.

Could the antediluvians, therefore, now make their appearance amongst us, their surprise would be awakened by the shortness of our spring and the length of our autumns and winters; they might perhaps chide the length of our annual revolutions and complain of growing old before they had fulfilled their wonted number of years. But this by the way.

It is evident from what we have stated, that there was a time when the earth in completing its year occupied only a few of our present days; on arriving at a greater distance from the sun, in completing its year it occupied the space of our present month; afterwards two months, then three, and so on successively till as the years lengthened they reached their present duration. Thus the planets which are nearer the sun reckon their years by our months; while those which are farther off extend the duration of their year so as to make it comprise several of ours. If Saturn divided its year into twelve months, a year of our earth would not equal two weeks of Saturn; the nearer, therefore, planets are to the sun the shorter are their years, the shorter, therefore, are the seasons of the year, and in this case a summer would scarcely last the length of our month, neither would an autumn or winter; as soon as the summer had commenced, autumn would supervene, which would be as rapidly followed by winter; thus after a brief interval summer would return with all the produce of its plant life, and the operations of nature would observe the briefest cycles. The summer, therefore, could not infuse any warmth into the earth which was not soon dissipated by the supervening autumn and winter; neither could the winter (so rapidly succeeding the summer and hence tempered by its lingering warmth)

occupy the zones with its cold, without the rapid return of spring and summer dissipating these chills.

The duration of the seasons thus being shortened, they would become as it were confounded, and collectively would form only one perpetual spring. Moreover, if the lengths of the days and nights were extremely short, the heat of a summer's day infused into the earth would become dissipated by the cold of the night and the cold of the night by the heat of the day. In this case the vernal temperature would be the same as if a thermometer were appended to a cylinder and the cylinder rapidly rotated before a fire ; in which case the spirits of wine in the thermometer would rise to no higher degree than temperate, unless the motion were too rapid. In this manner then the earth once enjoyed a perpetual spring, as indeed was maintained by the ancient philosophers, who were guided only by the light of reason, although the cause of the vernal duration was a subject of which they were ignorant. Ovid, therefore, makes the following beautiful allusion :—

> "The Golden Age was first :—when Faith and Right
> Were honoured, by no law enforced with fear
> Of pain or penalty . . . .
> Spontaneous earth, unwounded by the stroke
> Of share or harrow, gave them all her store.
> Content with food unlaboured, fruit they plucked
> Of arbutus, or mountain-strawberry.
> . . . .
> Amidst eternal Spring, the gentle breath
> Of Zephyr fostering cheered the unsown flowers.
> Earth gave her corn unploughed, and, year by year,
> Unfallowed, whitened fresh with plenteous grain.
> With flood of milk and nectar ran the streams,
> And from the oak the honeyed gold distilled."[1]

Again the poet, when signifying that the seasons were shorter than they are now, observes :—

> "When—Saturn down to darksome Tartarus hurled—
> Jove ruled the world, the Age, of Silver called,
> Succeeded, worse than that of Gold, but far
> Before the time of tawny Brass.

[1] *Metamorphoses*, lib. i., ll. 89, 90, 101-104, and 107-112, translated by H. King.—*Trs.*

'Twas Jove the limits of the primal Spring
Contracted, and, with change of seasons four,
Winter, and Summer, Autumn variable,
And shortened Spring, filled out the furnished year." [1]

Virgil :—

"I would believe that even such were the days that dawned at the first opening of the new-created world, and such the course they kept ; 'twas spring-time then, the mighty globe was passing a season of spring, and the Eastern gales restrained their wintry blasts." [2]

Alcimus Avitus :—

" Nor winter here held his alternate reign ;
Nor after winter chills shone burning suns ;
. . . . But here soft *spring* her constant reign maintained ;
Unknown as yet the ruthless southern blast.
And ever underneath the dewy heavens
Into clear air the gathering mist dissolved." [3]

The ancient philosophers, in their references to this period, thought that paradise was situated in some higher region than that occupied by the surface of the earth at the present day, so that they would seem to have imagined that the earth was nearer the sun ; and so Plato in his *Phædo* (§§ 109, 110) speaks of a certain ethereal earth. Hesiod [4] mentions the garden of the Hesperides beyond the ocean ; Moses also tells of a fiery flaming sword separating the first man from paradise.[5] Thus the whole globe was adorned with a kind of paradise as the result of a continuous spring time ; all nature was in her infancy, sportive and smiling. This was the time of the golden ages, when according to the philosophy of the ancients the gods were born. Then Flora and Ceres reclined eternally on the earth upon their grassy couches. Diana with her nymphs went through every wood. Jupiter, Phœbus, and the rest of the gods, lived in daily intercourse with men, and celebrated their loves in every grove. Pluto came forth from his Tartarean shadows into the light of day, and carried off Proserpine ; and Venus with her son Mars concerned themselves with love and battle.

[1] Metamorphoses, lib. i., ll. 113-118.—*Trs.*

[2] *Georgica*, lib. ii., ll. 336-339, translated by J. Lonsdale and S. Lee.—*Trs.*

[3] *Poemata*, lib. i., "De Initio Mundi," ll. 218, 219, 222-224.—*Trs.*

[4] *Theogonia*, ll. 214-216.—*Trs.*

[5] Genesis iii. 24.—*Trs.*

Had not an uninterrupted spring surrounded the earth, the earth through all its changes could never have received the seeds of things, nor have prolonged its existence for so long a time beyond the age of infancy, after having received life, as it were, in the womb of its mother; a kind of continuous spring was, therefore, the most efficient and almost the only means by which things could have been generated.

At the very time of creation it was commanded that the soil should bring forth its seeds; the seed its tender shoots and fruit; the sea its fish; and the earth its animals; not to mention other things which show that the Omnipotent produced and perfected the world by the use of means, which we may reasonably believe to have been those innumerable changes and that continuous spring by which alone the various objects of the world could have been brought into being. And how wonderful is it that the earth brings forth her seeds, which not only produce shrubs, and flowers, and herbs, but also continually reproduce themselves! How wonderful is nature also in the animal and vegetable kingdoms! Thus, although perpetual spring began gradually to leave the earth and recede far off, although winters and unequal autumns succeeded, yet all things continued their life as when they enjoyed a constant vernal temperature. We cannot but be moved, then, with a feeling of amazement, wonder, and adoration in the contemplation of all these signs of the infinite care and prudence of which they are the clearest evidences.

When, therefore, this globe became fertile in, beautified by, and adorned with plant life, and animals of all kinds had come into existence, then the first man was introduced into paradise, created to enjoy all the harmony of the visible world. He was made to be partaker of a more subtle or rational aura, in order that he might know how to render the world around him still more perfect, by accomplishing that which could be effected only through the medium of a living and rational agent endowed with a material body, a being able to enjoy the charms and varieties of nature, and become wise that he might venerate, love, and

worship that infinitely wise God who is the Author and Builder of the universe; and whose better and more refined nature, though clothed with a material garment, might aspire even to heaven itself. Oh! man, how happy, thrice happy thy destiny, born to the joys both of earth and of heaven!

CONCLUSION.

Indulgent reader, I have now placed before you a sketch of my philosophical principles, which reach from the first simple of our world to the ultimate compound, from the smallest invisible to the first visible thing, and, therefore, to the paradise of our earth; principles connected throughout, as I think, from one end to the other by intermediates. Whoever aims at laying down principles, and yet does not begin from the simple, and proceed in order to the last, cannot, so far as I am aware, perceive any just connection between them. For he who stops short in intermediates only, does not perceive the end of the series either on one side or the other, much less does he see whether these ends have relation to each other, or whether they are connected by intermediates. This was the reason which induced me to formulate a complete system.

That the principles here laid down are of the most simple nature, any one may see, and that they have consequently a perfect similarity to one another, in agreement with what we observe in the phenomena of nature. From the light of reason every one may perceive that nature acts with the utmost simplicity; that all the various things in the world have been produced from one and the same origin and cause; that this cause continues on through every derivative. In the simple itself is that one sole cause; it is latent in the first derived entity, or in what I have called the finite; indeed in this one finite are the two principles of nature, the active and the passive, from both of which the composite elementary exists; consequently in derivatives there is latent that which is in primitives, and the same is the case in regard to compounds and simples; in regard to effects and causes. Thus nature has her residence always in the cause,

and reappears in every effect; whoever, therefore, seeks for her in the effect, will be able to find her in the cause.

Since then nature acts by the most simple laws, it may be well to offer a brief summary of the whole of my philosophy. Let us begin from the first simple. 1. In the simple the internal state is a tendency to a spiral motion, and, consequently, its endeavour or effort is of a similar kind. 2. In the first finite arising therefrom there is a spiral motion of the parts, as is the case also in the other finites, so that there is a similarity in all the finites. 3. From this single cause there results in every finite a progressive motion of the parts, an axillary motion of the whole, and, if nothing prevents, a local motion also. 4. If the motion is local the actives arise, one similar to the other. 5. From finites and actives arises the elementary, one similar to the other, and differing only in degree and dimension. It is, therefore, evident that I conceive the existence of only three kinds of bodies, namely, finites, actives, and the compounds of these, or elementaries.

With regard to finites, I have stated that one is generated from the other; that all the finites thus arising are perfectly similar to one another, differing only in degree and dimension; that the fifth finite is thus similar to the fourth, the fourth to the third, the third to the second, the second to the first, and the first to its simple; so that he who has learnt the nature of one will have learnt the nature of all. In the same manner the actives are all perfectly similar to one another; the fifth, fourth, third, second, and first, being all of the same nature, and like the finites, differing only in dimension and degree. The elementaries, moreover, are similar to one another, being compounded of the passive and active, or of the finite and active, finites occupying its surface, and actives its interior; hence the first, second, third, fourth, and fifth elements are all similar to one another, and he who has learnt the nature of one will have learnt the nature of all.

I have stated also that in every finite there are three distinct motions; a progressive motion of the parts, an axillary motion, and, if nothing prevents, a local motion; that, so far as I am

aware, these are the only motions in nature ; or at least, if the motions of bodies be granted, it cannot be denied by any rational being, that of all others these are the most highly adapted to the operations of nature. I also state with regard to these motions, that they also proceed from one and the same source or cause—the spiral motion of the parts ; and that since this motion is most highly natural, it is also most highly mechanical, being endowed as we know with every possible mechanical potency and force ; and that if it be granted that motion is the cause of things, no other motion can be granted than the one which is highly mechanical. In the simple, however, since there is nothing substantial in it capable of experiencing motion, we must instead of motion conceive of state, or of effort arising thence, as it were, from one such motion to another such motion ; a state in which the sole cause and primary force of all the things which subsequently exist is latent. The whole of our elementary philosophy consists of these principles, of which we have here given a summary.

The reader may obtain a fuller view of these principles by taking a cursory glance at their exposition, beginning from the point and tracing them to the end. In propounding these principles, I do not seek to gain the favour of the learned world, nor do I desire renown or popularity; I wish to make these things public, led only by the love of the truth. To me it is a matter of indifference whether I win the favourable opinion of all, or of none, whether I gain much or no commendation ; such things are not objects of regard to any one whose mind is bent only on truth and a true philosophy. If I should happen to gain the assent or approbation of others, I shall receive it only as an indication that I have pursued the truth. I have no wish to persuade others to lay aside the principles of various illustrious and talented men and adopt mine. It is for this reason that I have not referred to the philosophy of any particular writer nor even hinted at his name, lest I should seem to wound his feelings, impugn his sentiments, or detract from the praise which others bestow upon him. If the principles I have advanced have more of truth in them than those which are advo-

cated by others ; if they are truly philosophical and in agreement with the phenomena of nature, assent will follow in due time of its own accord. And, should I not gain the assent of those who have already embraced other principles, and can no longer form an impartial judgment, still I shall gain the assent of such as are able to distinguish the true from what is untrue, if not in the present, at least in some future age. Truth is but one, and will speak for itself. Should anyone desire to impugn my sentiments, I have no wish to oppose him ; but should he desire it, I shall be happy to explain my principles and reasons more at large. What need, however, is there for words ? Let the thing speak for itself. If what I have said be true, why should I be eager to defend it ?—surely truth can defend itself. If what I have said be false, it would be a degrading and silly task to defend it. Why, therefore, should I make myself an enemy to any one, or place myself in any opposition to him ?

I cannot conclude, however, without referring to the name of Christian von Wolff of our age, who has given so much attention to the cultivation of his intellectual powers, and who has so much contributed to the advance of true philosophy by his various scientific and experimental researches. I refer more particularly to his *Philosophia Prima sive Ontologia*,[1] as also to his *Cosmologia Generalis*,[2] in which he has formulated various rules and axioms to guide us in our progress to the attainment of first principles, a perusal of which has served very considerably to confirm my views ; although the principles laid down in the present work had been worked out and committed to paper two years before I had an opportunity of consulting his works. In the revision of the present volume I acknowledge myself much indebted to his publications ; so much so, that if anyone will take the trouble to compare the two, he will find that the principles I have here advanced and applied to the world and its series, almost exactly coincide with the metaphysical and general axioms of this illustrious author. We cannot but acknowledge, therefore, in

[1] Published at Frankfurt and Leipsic, 1730.—*Trs.*
[2] Published at Frankfurt and Leipsic, 1731.—*Trs.*

the words of this learned writer, "That in philosophy we must grant a place to philosophical hypotheses, so far as they prepare the way to a clear discovery of the truth." Again: "Science can make no progress without freedom to philosophize." Again: "Full liberty must be granted to all who philosophize in a philosophical manner, nor have we any reason to apprehend from such a liberty any danger either to religion, to virtue, or to the State."

THE [MINOR] PRINCIPIA;

OR

THE FIRST PRINCIPLES OF NATURAL THINGS

DEDUCED

FROM

EXPERIMENTS AND GEOMETRY

OR

A POSTERIORI AND A PRIORI

A POSTHUMOUS TREATISE BY

EMANUEL SWEDENBORG

TRANSLATED FROM THE LATIN BY THE
REV. ISAIAH TANSLEY, B.A.

THE [MINOR] PRINCIPIA.

1. A PHILOSOPHICAL THEORY CONCERNING THE ORIGIN OF NATURAL THINGS.

For a long time it has been a subject of discussion with the learned whether natural philosophy, throughout its whole extent, is based on the same fundamental principles as geometry, that is, whether nature as given to us by the Supreme Will is simply geometrical, or, to use a freer term, is entirely mechanical, or whether all the operations, phenomena, and elements of nature proceed by a kind of mechanism, and like that which we have long known and been familiar with through geometry. Some take a negative view of this, but others assent to it, because almost all the constituent parts of figures, masses, stable bodies and forms are invisible, and have not yet been revealed by experiment and rational investigation; consequently they consider that some of the philosophers of our country take refuge in the same ideas as the ancients, preferring to resort for an explanation to occult qualities, and to conceal their ignorance under fallacious conceptions rather than to bring that to the light which they foresee will be disproved by the learned of a subsequent age. But others maintain, and try to prove, that nature is wholly and entirely mechanical, and that everything that takes place among invisible particles proceeds geometrically, acknowledging that the only difference is that which exists between greater and less. For they think that nature acts in the same way in the least things as she does in the greatest; and they rest satisfied to prove this by examples; seeing, as they do, the same characteristic of analogy and law when they deal with vast quantities as when dealing with infinitely small ones. For these reasons they desire that nothing in nature should be

considered occult, except where phenomena have not yet come to our knowledge through the understanding and experiment.

Since, therefore, in things of a larger kind, and apprehensible by our senses, nothing has hitherto been found to exist that does not acknowledge geometrical rules, and as all nature is visible, I consequently know not whether it is permissible to take refuge in something of an occult nature, and in a quality other than that which is based on exact philosophical principles. I also know not whether the human mind can rest in, and, in a way, acknowledge a theory which is based upon a mechanism either different from, or ampler than that which has long been made known. In order that the truth may be more evident, I desire to deal with those first principles which have been set forth both by experiment and geometry, that is, a posteriori and a priori. I, therefore, fully hope that it will be seen, whether the mind ought to be content with occult qualities, or with those that are placed, as it were, in the light of geometry. Those who desire to search out the matter will find that natural philosophy and geometry have the same origin. If, according to our thesis, it is true that there is nothing in nature that is not geometrical, then the origin of nature and geometry must be acknowledged to be the same.

In geometry the mathematical point is the primary entity. From this arises the line, as a result either of an infinite series of points, or of their motion; then from this stream an area is derived, and from this again a solid body is said to originate. And thus geometry takes its rise from a formless and imponderable point as if from something unknown. Geometry can describe the nature of the point only obscurely by means of words. It cannot be said at all to have substantiality, since it gives birth to the line, the area, and by manifold motion, a solid. But it is regarded as unknowable, and non-conceptual, in order that something capable of being known may be arrived at, as is the case with respect to differences in the calculus of infinities. Geometry, however, is not in fault, since the primary entity is hardly capable of being defined except by bare words; it cannot be visualized.

If we wish to think of the nature of the world before its existence or creation, when as yet there was no matter, nor even the point, by whose movement or flow, the line or the solid could arise, then we must conceive it as being absolutely empty, or that in the place of the world there was a kind of immense void in which there was nothing whatever that would seem capable of giving rise to matter. At that time such a point flowing of itself or from another, could scarcely be conceived, or anything finite. Consequently our philosophy or reasoning concerning the beginning of things ought to go still further back, and consider whether in that absolute void something may not be comprehended that could give origin or birth to some entity from which the line, the surface and the solid might be produced.

If a kind of void be granted in which nothing existed that could move in a material and geometrical sense, much less produce anything, then it must be entirely infinite, and have existed before geometry; this was primitive nature which obeyed no geometrical laws, such as they are known to us. Geometry had not yet been conceived or born, since the point which could flow or move mechanically did not exist in nature. In this state even our mind is blind; there is nothing here except what is infinite and surpasses our comprehension. Nor does the matter seem capable of being expressed in any other way than this, that the beginning of regular and geometrical nature was an immense void, and that the primary origin was only infinite motion in an infinitely small point. But in using such an expression we seem to trifle with words, since we cannot form a conception of infinite motion, apart from something moving or moved, nor of such motion in an infinitely small point where there is no space, in which case two infinites may here be supposed — in motion, the infinite of velocity, and in place, the infinite of smallness. But because such infinity cannot be apprehended geometrically, we must consequently have recourse altogether to something of an infinite kind, and a self-originating nature, or a Supreme God and prime mover must be acknowledged, who is without any geometrical attribute or

quality, who alone is greatest and least infinite motion, and who by His own infinite motion in an infinitely small place gives rise to the point from which geometry has its commencement and origin, and according to whose rules the whole of nature then acts.

We, therefore, carry our reasoning through these infinities up to a certain primarily existing entity or point. For we can only define this point as having originated from infinite motion in an infinitely small space; consequently from such infinity something definite existed, that is, the first natural point, from which all other things derive their origin; and together with this very point geometry, or nature bounded by geometrical laws, was born. This point seems to be something between the infinite and the finite. It participates both of infinite nature, which has no geometrical rules such as our world has, and also of geometrical nature. By means of this point one is permitted to enter, as it were, through the door into the presence of that nature which appeals to and is adapted to our senses. That from something infinite the finite can arise is proved by the infinitesimal calculus; and geometry also acknowledges the fact, that from the motion or infinite fluxion of points something of a finite character is determined, whether it be the line or something else. The science of physics also which regards matter as infinitely divisible proves the same.

2. The infinite as well as the finite motion of the first natural point generates the line, the surface, and the solid.

We assume this natural point to be almost the same as the mathematical point. This is the beginning or primary entity of lines, consequently of figures, and thus of the whole of geometry. It is the primary entity of the lines that exist in nature, and, consequently, of solid bodies, and of the whole of nature. This is defined as non-infinite or as partaking of both. But how this was able to generate the finite has been stated in the preceding paragraph. It is not for us to determine how, from infinite things, something finite can be produced; but since nature, or

that nature which follows natural and geometrical laws, begins here, therefore a beginning must be made with this point—which is defined by some part of itself—and not from that which is purely infinite.

Since motion alone seems to have produced this point, therefore no other figure can be ascribed to it than that which agrees with, and is most adapted to motion; and this figure is the spherical one, of which we shall treat further in the following pages. Consequently, the figure must be like the motion which produces the spherical form.

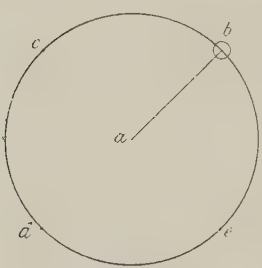
Now, let this natural point be of any figure whatever, it is sufficient that it is something finite, and limited, as it were, by motion or by its primary source.[1] Let it then be assumed that such a point moves with very great velocity along a certain line, that is from one end of the line to the other, and that this motion returns upon itself, so that if in fig. 1 the point in *a* is carried with very great velocity from *a* to *b*, and back again from *b* to *a*, and in this way continuously throughout the same line back and forth; then if the velocity is very great, or if, first, we suppose the velocity to be infinite, then at no moment is there an interruption in the movement of the point, and since there is no break, but the movement due to the infinite velocity is continuous from one end to the other, a line is formed, just as if an infinite series of points constituted such a line. The idea involved in this supposition can be made clearer by an example. If a ball of lead or of some other substance be rotated round a definite axis or centre with very great velocity, a continuous surface, as it were, is formed. Thus, in fig. 2, if the ball *b* be very rapidly revolved in the circumference *bedc* by the radius *ab*, and if the velocity be very great, then to all intents and purposes a surface hard and unyielding is formed in every place by the like body *b*, since at no moment is there a visible break when *b* is in motion,

Fig. 1.

[1] *From the margin of the MS.* Let the point be finite and the motion infinite.

but, according to our conception, it is in every point of the surface at the same instant. If the moving force were hidden from our sight, that is, if the means of movement were invisible, and only the moving ball seen, and if the circular movement were very rapid, the mind would be able to perceive nothing but a continuous, and, as it were, quiescent surface; for in no place would the ball be seen to delay or rest in any point, but to be present throughout the entire surface. This becomes clearly evident when a wheel with one or several teeth is caused to rotate, something continuous and not divided into teeth is then seen. Still more would it be believed to be a continuous and perpetual circle if the motion were that of infinite velocity, or approaching proximately to infinity. Then there would be nothing that did not prove continuity; the ball would be at *c* and *d* in the same instant that it was at *b*, and so throughout the entire circle. Consequently, by the extremely rapid movement of a single finite point, whether along a line or throughout a circle, either a straight line or a circle might be formed, just as if an indefinite number of points were able, without motion, to form the same line by being joined together in a series. The truth of our proposition consequently is clear, that is, that the natural or infinite, as also the finite motion of a first point, can produce a line; this takes place as well visibly as invisibly.

Fig. 2.



In the same way a surface, either linear or circular, can be formed, that is, by the help of a very rapid movement. If in fig. 3 this point moves from *m* to *s*; but on the way takes a downward and an upward direction, so as to proceed from *m* to *n*, then upward to *o*, and so on, until it comes to the end *s*, returning back again by the same way to *m*, then I maintain that this same simple point is able to trace out a kind of plane

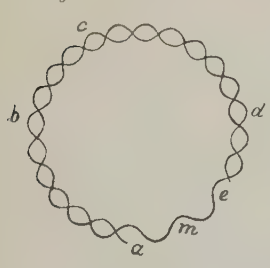
Fig. 3.

surface. In order to put the matter more clearly, let the motion of this point be an upward and downward one, or let it be undulatory, as it were, during the path which it traverses from *m* to *s*; and let the undulation be very small, with no break recognisable, and let the motion be one of infinite velocity, then the plane which the point has traced out by its movement must be considered as formed of continuous and connected points. By reason of the velocity no break can be conceived, but in every place the point makes itself felt and is apparent, since the interval of time between its presence in two different places is so small as to be imperceptible. In the same way, if the undulation is still greater, or a kind of wave motion as in fig. 4, so that the point is carried with very great velocity from *u* to *w* by the undulation or wave motion shown in the figure, and let it return in the reverse direction by a similar undulation, but not along the same path, then again a kind of plane surface is formed by the extremely rapid movement of a single point, which I desired to show for the sake of demonstration; not that I hold that the point is carried along by this motion.

Fig. 4.

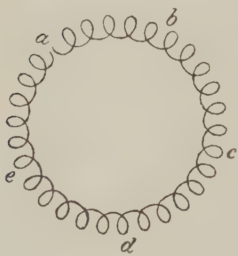
So, too, a circular plane can be formed in the same way, and traced out by a single point actuated by a very rapid motion. As for example, if in fig. 5 the point flows from *a* to *b* and *e*, and thus to its place of origin with either a tremulatory or undulatory motion, nevertheless in such a way that the continuous undulation does not proceed along the same path, consequently—just as was noticed in regard to the surface or lineal area—a portion of a surface, or a part of a circular area is formed; or, if in fig. 6 the point flows in a circular manner, and thus completes the whole larger circle *abcde* by a circular motion. And if the point is so deflected,

Fig. 5.



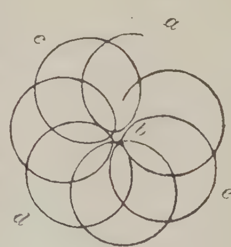
and so proceeds throughout the entire periphery, that this circular rotation does not continually return to the same places, but is always changing, and if then the motion is very rapid, part of a circular area, or a kind of denser surface is formed; because, as previously stated, no perceptible break intervenes in its passing from one part to another; and since no other idea can be formed than that the point is continuously in every part, and that, provided the velocity of the point is sufficiently great, there is an unbroken series of points.

Fig. 6.



In the same way an entire circular area may also be formed. Consider fig. 7. If the point flows from a to b, or to the centre and so throughout the circle to the periphery in c, and back again to the periphery, and so on continuously by means of a kind of circular flow from centre to periphery, until it has completed the entire greater periphery; if again by similar circles but not the same path, the point completes a greater circle, then if the velocity of its flow be very great, and no perceptible interval intervenes between one part of the circle and another, but it is found within any inappreciable interval in any place in the area, then, it can be affirmed on the same basis, that the point is in every part, and that a circular area is formed by means of a single point endowed with very great velocity.

Fig. 7.



But before we proceed further, let us see whether in the nature of things such a velocity is possible that a circle and an area may be formed from a moving point. First, we must consider that the motion exists in a place where there is no resistance, and where it can increase to infinity. At another time I should prefer to state this instead of using an example, although an example would rather illustrate than prove it. It is

an undoubted fact that our earth moves about its axis, and that every twenty-four hours it rotates once round its centre or central line. If then we consider some point, or a tiny particle of dust at the equator, where the circle is greatest, then that point, although at rest, is nevertheless carried round with the revolution of the earth, and within twenty-four hours has completed 5400 German miles, or 64,800,000 Swedish ells, or, in every second, 750 such ells. Let it be supposed that the point is impelled with the same velocity round a circle with which the said dust-particle is moved at the equator; and suppose, also, that the circumference of this circle which the point describes is equal only to the thousandth part of a line in that ell, then this point, if carried along in a second of time with the same velocity as that of the dust-particle, would move round the circumference of such a circle 1,800,000,000 times. And in this case, the point must be considered to be in every part of the circle, or in every part of the surface or area in such a way that the circular area, according to our understanding of it, is able to be traced out by means of motion and flow alone. But these things have been adduced merely for the purpose of illustration, not as a proof; especially since the small particle with the circular motion is at rest, and this point describes an infinitely smaller circle or circumference than that which has been taken as an example.

We have now laboured sufficiently to show that a line or surface can be formed by the motion of a point, consequently, it is not difficult to prove that a solid can be produced [by the same means]. If the point by its motion forms not only the entire surface of a circle, but, in the very formation of the surface, describes infinitely small circles, or forms very minute surfaces, in such a way that the entire surface consists of an infinite number of circles described during the process, then also a sphere results which may be designated a solid. For in this case the point is carried along, not only in the direction of a line, but also laterally throughout a surface; and by means of circles formed during the process, or continuous circumvolution, a real solid is duly formed. But

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this cannot be easily made clear to the eye, until those things that follow are seen; for we shall afterwards deal fully with the movement of the point to a complete result, and with the formation of a spherical particle by means of such movement.

3. The motion of the natural point proceeds by means of circles.

Here we must consider the character of the motion, whether it proceeds along a right line or throughout a circle. We must conceive that this motion takes place in an empty space or vacuum, where there can be no strain from one place to another; no force which either tends toward or from the centre. When the motion is in a definite element, as for example in our atmosphere, then it takes the direction of a right line, so that if a body falls of itself from a height it tends to the centre, and, at least to our eyes, falls perpendicularly in a right line, since there is a certain force which directs the body as it falls along that line. Equally so if it is thrown upward along the same path, or the same perpendicular. So, too, if it were propelled horizontally, and there were no tendency toward the centre, it would be carried horizontally, or parallel to the horizon without deflection. The reason is, that this takes place in an elementary sphere, where the question of place to place is involved, where vertical and horizontal lines have to be considered, and where the impulse or the linear movements are under the direction of a centripetal force. But here another consideration comes in, since there is nowhere up or down, horizon, quarter, or direction of place to place, but a kind of void, in which there can be no consideration of a centre in respect to other particles, or in respect to anything material. In such a condition of the world a right line cannot be conceived, that is, a line which stretches from one point to another, and gives rise to intermediate distance. Distance cannot be conceived, since place cannot be conceived. As, therefore, there is nowhere either up or down, left or right, but things must be conceived in reference to a single motion,

therefore that motion includes everything which is elsewhere considered in regard to place or impulse.

Let there be motion, therefore, under such conditions; then it cannot be conceived otherwise than as operating everywhere, and embracing all those points which come under the name of quarters; as being in direction both upward and downward, left and right, and as proceeding everywhere in its own sphere. Consequently, that motion must be conceived as circular, which nowhere has a limit, and nowhere a determinate place; nor has it any relation to those things which come to our conception in the vortex and sphere through elementary centripetal particles. I confess that these things are somewhat obscure, and that it is very difficult to form a conception of motion in a circle and of motion from place to place along a line in a vacuum, where place cannot be conceived. An explanation cannot be sought from geometry, since geometry can here determine and indicate nothing, as there is no matter involved, which geometry has for its sole basis. Nevertheless, since geometry cannot explain how a finite point can describe a line, and measure out a definite space, when nothing can be conceived as tending hither or thither, we must have recourse wholly to a motion that has nothing in common with motion in an elementary state, but which includes every kind of motion, that is to say, we must come to circular motion.

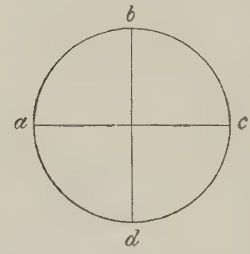
As to the origin of motion and the primary impulse, the occasion for explaining these has not arisen. We shall deal with this later, in paragraph 23, which please connect with the present one.

4. The motion of the natural point proceeds by a circular spiral, that is, by a spiral line, whence arises figure, or the primary particle.

In the preceding paragraph it has been stated that a point moving in a vacuum cannot be impelled and driven along a right line, because nowhere could a line come under consideration as taking a reclinear path; but the motion runs entirely into the

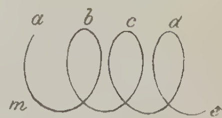
circular form, that is to say, into that line or figure that has none of those directions that elementary nature affords. From similar reasoning it follows that the point in motion cannot be impelled simply into a circle; for if this were the case, it would immediately take its direction into one quarter. A circle tends to one quarter by virtue of its diameter. For if the area is considered as plane, this plane would extend from one extremity of the diameter to another, and consequently there would be no direction to the remaining parts. As for example, if, in fig. 8, the point were to flow continuously from *a* to *b* through *c* and *d*, and so on uninterruptedly from its place of origin and back again, and thus formed a circle by a continuous movement throughout a circle and formed a circle; and if *a* be the quarter of origin, or the left hand, *c* the quarter of termination or the right hand, if the moving point always completed this circle from the former quarter to the latter, or from left to right, it follows therefrom, that the motion is linear, as it were, and tends to one quarter, nor does it cause any lateral motion to the south and north, or intermediate points, consequently such circular motion cannot be conceived, when a linear motion cannot be conceived. It follows from this reasoning that the point moving in this vacuum tends to all points, and by its own motion forms not a circle, but a complete surface, that is to say, it is carried equally to all points, or in all directions, and thus marks out a surface by its own motion.

Fig. 8.



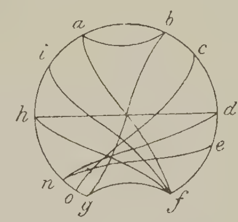
But since such motion throughout a circle is difficult to conceive, it consequently can be represented only by a circular spiral; not indeed by such a spiral as tends in a longitudinal direction, as in fig. 9, from *a* to *b*, *c*, *d* and *e*, since it would then be immediately in the direction from *a* to *d*, or from *m* to *e*, and then by its own motion it would describe a definite right line; but

Fig. 9.



such a spiral as would be continued throughout a definite sphere, and which, by its movement, would form a surface, or which would mark out and touch all the points of a surface ; as in fig. 10, if the point is carried from b to g, from c to o, from a to f, and so on throughout, in such a way as to form a definite spiral in the surface itself, that is, that at every instant it is deflected from a circular right line to the right or the left, and for that reason takes a spiral course throughout the same spherical surface. This motion can be better conceived by the imagination, than from a figure. Now conceive a spiral motion, but which tends in no direction outside the surface, but which remains always in the same figure or surface of the sphere, in such a way that the spiral twist takes place in the spherical surface, but not in any part outside the said surface ; if, then, a spiral circulation of the point be conceived throughout the sphere or surface of the sphere, but not outside the same, it thence follows that the point by its own flow does proceed in one direction rather than another; but it flows in such a way, that it is carried in all directions at the same time, and, consequently, by its flow marks out a sphere or the surface of a sphere.

Fig. 10.

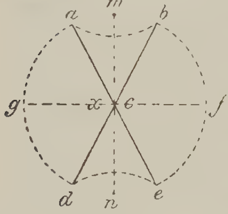


5. When the natural point moves in a spiral manner over the sphere, there is a space around the poles where this point does not come.

Suppose now that the spiral movement of the point over the sphere is according to the mode which has been stated, that is to say, that in its movement it is always being deflected from one point to another, also to another circle of the same sphere, and in this way forms a spiral, it follows from this, that it can come only within a certain distance of the poles. For example, in fig. 11, if one pole is at m, and another at n, then from the spiral motion of the point moving from d towards b, or from e towards a, it can never approach nearer to the pole m, than is

indicated by the distances *mb* or *ma*, that is to say, its distance from the poles. This distance is formed along the first direction. The spiral movement over the surface of the sphere causes the point to be borne in the same way along the equatorial line, just as takes place in the sphere; consequently, when it reaches the highest point either *b*, *e*, *a* or *d*, it is deflected back again, and, consequently, describes a kind of circle round the poles, this circle being formed of pure circles, which pass through the point of contact of that circle; nor does it approach nearer to the poles *m* and *n*, or depart farther from them. Therefore, it follows that the locus *amb* and *dne* in the sphere is never touched by the moving point, and, consequently, the surface of the sphere is lacking here, the surface being broken, as it were, in that section. Elsewhere the surface is continuous, resulting from the extreme velocity of the moving point, but in these places, or in these loci *ab* and *de*, it is broken, there being a gap, as it were, and the circle is incomplete, because the point is never able to enter this section of the sphere. The reason is, as previously stated, that the spiral tendency of the point, always preserving the same distance, tends in a lateral direction in its rapid progress round the surface.

Fig. 11.



For the sake of example, let the point move from *c* or *m*. But, since its motion is spiral, when it has described its circle, it does not return to *c*, but has moved from *e* towards *x*. Let the distance *ex* be twenty degrees, that is, when the point passing through *c*, having described a spiral circle, returns to the same line, it has been carried from *c* to *x*, then it follows, that when it reaches the highest point, or, when a fourth part of a circle has been described, it will have been carried as far as the fourth part of the same, that is to say, as far as $\frac{20}{4}° = 5°$. It follows, then, that this point does not approach nearer the pole *m* than the distance of five degrees. But, when it has returned to the line *gf*, it will have been carried from *c* towards *x*, to a

distance of twenty degrees. In the same way if it moves from x to m, it will be carried through the spiral traced out from m to a distance of five degrees ; so also in *de*, consequently there is also a fourth part of the degrees round the poles as there is around the equator of the same sphere. The reason is evident ; for when it crosses the equator, it always strives towards a pole, and has a tendency to reach it, unless the direction is lateral along the equator, that is to say, spiral.

Or, if the distance *mb* is twenty three and a half degrees then the movement of the point in the equator *fg*, in any circuit whatever, would be ninety-four degrees, whence the distance of the circle *ahb* is greater from the pole, and this section *ahb* is clearly a gap, there being no flow of the point there, and consequently no surface.

It is, consequently, evident that, by the aid of the movement of the point throughout the spiral round the sphere, two poles are formed, and that there is another motion of the points around the poles, which forms the section of the same sphere or surface. The circle of this section is touched only by the movement of the point ; for the point cannot come within this circle.

6. This movement of the natural point may also bring an equator into consideration.

Since there are two poles, and a space like a vacuum around the poles, there is consequently also a line or intermediate circle, which must be called the equator. For if all the lines be cut in the centre, that is, if all those lines—which are spiral—are bisected, an equatorial circle would result from that bisection.

7. The line which cuts all those spiral lines at right angles, forms a kind of ecliptic, and this ecliptic has a definite or fixed node or intersecting point with the equator.

When, then, the point moves spirally, in the way which we have just laid down, not only is there a kind of similarity to poles produced, but a line midway between the poles which in the largest circles is called by the general term, equator ; and in the smallest

circles it may retain the same name or designation on account of the similitude, or rather identity, of the subject. But as to the ecliptic, it also is formed by the spiral movement of the point, that is, it is a circle which has a different centre and different poles from those of the equator. The pole of the ecliptic is in that circle which is formed round the poles in the circle of the section which surrounds the poles, which has been shown to be vacant.

Let that spiral be considered which cuts the equator obliquely; the obliquity of the section is not everywhere the same, but in one part it tends to the right, in another to the left. But if all these things were described, and illustrated by figures and drawings, it would involve much labour, and even then the idea would hardly become clearer to the reader. It is not difficult for any writer to set out diagrams of such things so as to form circles with mutually intersecting lines, and by various calculations to determine the angles, and prove everything geometrically. But such demonstrations are frequently published by those who are content to make easy things difficult, to turn light into darkness, and tie up everything into riddles and knots, believing that the learned world will venerate the teaching on that account, and will, in consequence, exalt the ability of the authors above that of others; when, nevertheless, it would be very easy to eliminate all those obscurities and difficult points, and by the bare help of a few pages to place before the eyes of the reader all those things with which they had laboured to fill volumes.

As to these spiral lines and tendencies it would also be easy to explain the obliquity of the circles, and the very varied sections in regard to other circles, so as to make it a laborious task for the reader to unravel everything. Hence, as the end is only to treat these things in a plain and simple manner, and the more so, since of themselves they are not easy to understand, our only object is to put the reader into such a position that the ideas and the very truth itself may stand clearly before him.

Take, then, a sphere made of wax or wood, and describe thereon the equator and the circle about the poles, and spiral circles from the extremity of the section throughout the equator to the other

extremity of the opposite section, and thus throughout the complete spiral; and let the lines be so traced as make them quite visible. Such a mechanical tracing out of the circles will make plain to the eye the whole movement of the natural point about the sphere, and will make conspicuous how obliquely the equator is cut in some parts, how in others the section is less oblique, and how the obliquity is changed in another part of the sphere, and at length, if it is carried farther, how there is an alternation, and how they cut this equator differently.

If these spiral circles are cut at right angles, and indeed, in the middle, that is to say, if a circle is described through all those spiral circles, which cuts the former at right angles, the question of an ecliptic will at once arise, and by the same process it will be seen that there will be a definite pole of the ecliptic, which pole, by the uninterrupted movement of such spirals, proceeds, and is also transferred throughout its own circle. This can be experimentally proved. If the same spiral be traced again and again on the wooden sphere, or if the delineation or tracing be carried uninterruptedly round that sphere, then another situation of the spirals will be seen to arise, and the equator will be found to be cut in a different way. Consequently, the pole will not remain in the same part of the ecliptic, but will advance gradually along the circle.

For the same reason it follows that this ecliptic circle does not cut the equator always in the same place, but that the section gradually moves across it, which simply means that the nodes are changed. If the place is changed, either the pole of the ecliptic is differently transferred, and, therefore, the node also moved, or the junction of the ecliptic with the equator is moved.

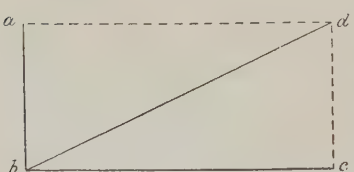
8. The passage of the point along the ecliptic takes place at equal distances, but those distances may be greater or less according to the velocity of the motion.

As to the first consideration, the passage of the moving point along its ecliptic, it can be seen at once that it takes place

uniformly, that is, by distances that are always the same. For if the spiral is regular, then the point moves along that circle uniformly, but along the equator variably. In this movement there cannot possibly be any irregularity; for there is nothing to retard or accelerate the motion, there is nowhere any upward or downward, and consequently no retardation or increase of motion; therefore, the movement of the point toward the ecliptic cannot but be regular. Whence in the greater circle the ecliptic is divided into three hundred and sixty equal degrees, which our earth or planet describes daily, or in equal times, in such a way that it passes through one degree each day. If we consider the nature of this spiral, we shall see that it returns to its own intermediate line or ecliptic with every revolution, but that the point has been transferred further, which forward movement takes place in equal times or at every revolution.

If this spiral movement arises from the compounding of two motions round the same circumference, and the movement is equal all round, it is also equal on both sides. That circle which cuts perpendicularly any circle whatever will be everywhere distinguished by an equal section and transference, just as if, in fig. 12, a motion from *a* to *b*, and from *b* to *c*, were uniform, but the time occupied were the same; then the same body would move with greater velocity from *b* to *c* than *a* to *b*. If a body were impelled at these two rates, then, in the same time, it would be carried with uniform velocity from *b* to *d*. The reason of this is, that as the body is under the influence of two uniform velocities, the resultant velocity is uniform, just as is the case with circles.

Fig. 12.



But if the first or vertical motion which completes the circuit is not so great, then a longer time will be required before it returns to its ecliptic, and consequently a greater velocity of translation or progression is possible in the ecliptic; therefore from the

velocity of the motion of the point there will be a greater or less translation along the ecliptic. Still, we must candidly confess that it is by no means easy to find out what is the difference between the motion or translation of the point round the circuit and its progress along the ecliptic. For it is possible that in three hundred and sixty revolutions it passes along the ecliptic once, and it may also accomplish this in no more than ten or fifteen. This results from the primary impulse of the motion. Still, I do not doubt that the reason and a clear explanation may also be brought forth to light.

In the larger circle we see that there are three hundred and sixty revolutions possible before the ecliptic has been once described; in the case of the planets more or less distant, more or fewer revolutions are possible before they have traversed the ecliptic once. But we must treat of these subjects elsewhere; and as a full explanation would be necessary and considerable labour required, it is sufficient to indicate the nature of the motion. For being still on the threshold of the subject, it is not yet the time to pass to more interior matters.

That the primary motion of the point follows the course of the spiral in the sphere I propose to demonstrate more clearly in the following pages; here it is sufficient merely to indicate that the motion of the greater circles necessarily arises from the nature of the smaller ones. Motion in the least circles rules and governs, as it were, motion in the greatest circles. In the greatest, it is perfectly clear that the motion is along the equator, that it is along the ecliptic, that there are two opposite poles, that there are poles of the ecliptic which are distant from the poles of terrestrial poles twenty-three and a half degrees, that a body is carried along the ecliptic uniformly through distances that are called degrees. Now, since our philosophers see the progression of the nodes, or the points of intersection of the ecliptic with the equator, to be carried along at the same time, they form the idea of a spiral movement. It is just the same in the smallest things which originate motion in larger bodies. For in the volume the same motion is copied as that which is found in each particle of

the volume. But the truth of this will be more fully seen in the following pages.

9. THIS NATURAL POINT WILL RETURN TO THE SAME PLACE IN THE ECLIPTIC ONLY AFTER AN INFINITE NUMBER OF REVOLUTIONS; AND THIS IS THE REASON WHY A PERSISTENT AND, AS IT WERE, CONTINUOUS SURFACE IS FORMED.

If the point moves along the ecliptic with always equal degrees or distances, it does not thence follow that the distances or degrees are such as to divide up that circle, that is, the ecliptic, equally, and in such a way that the point would return to the same spot after one circuit of the ecliptic. If now, a circle, or the zodiac, were divided into three hundred and sixty degrees, and a point were moved one degree by any revolution, then necessarily it would return to the same spot or to the same place in the zodiac, provided it described that circle once. But it rarely happens in spirals of this kind that a point returns to the same place, or that it so divides the circle by such an always identical and equal translation, as to cause the point to return to the same place. For if there were any break, then the moving point would immediately come into parts of the zodiac other than would be the case if there were no break. And if the break were of such a kind, then the point would never be able to return to the same place in the ecliptic, except after an infinite number of revolutions. It consequently follows that if the division is not equal, or the translation of the moving point through the ecliptic is according to equal divisions, then it will arrive at the same place only after countless revolutions.

If, for example, a circle is unequally graduated, and the divisions are broken up in such a way that at the limit or about the place where the graduation begins, the reckoning does not fall or terminate in the same place, it advances thence to other parts in the same circle, and although it marks out equal distances, yet returns to the same place only after many, and frequently, an infinite number of revolutions. For example, let any motion

whatever take place in a circle, of twenty-three and a half or forty-seven degrees, it will not return to the same place or the same point in the circle in which it began. So also we may suppose it happens here.

If, therefore, the translation or movement of the point along the ecliptic is uniform, yet such that the point returns to the same place only after many revolutions, then necessarily the surface which arises from the flow of the point will appear to be a continuous surface; for at no conceivable moment is the point found exactly in the same place. This is effected by the rate of the motion; and, since there is no perceptible interval of time, the surface clearly appears to be, as it were, continuous, and the point to be perceptible in every part of it. If, then, such a movement be conceived, it must necessarily be conceived always present and everywhere unbroken, just as if the surface consisted of an infinite number of points, and had no break in it.

But if the point were to move along its ecliptic with uniform velocity, then a gap might be conceived to exist amongst those degrees or intervals along the distance traversed, but these would vanish if it did not return to the same place, but proximately, and so on continuously throughout the whole ecliptic.

10. This flow of the natural point is continuous and everywhere equal.

We shall give some little consideration later to the nature of the first impulse or motion of the point. But this impulse having been given, and a beginning having been made in the movement of the point, we say, then, that the motion so imparted to it is continuous, uninterrupted, and without fear of diminution. The space in which the point moves must be regarded as a perfect vacuum, free from any matter whatsoever. In that space there is nothing but the primary motion of the point, whose mechanism we are unable to discuss because it existed before the origin of any mechanism. If, therefore, this motion has been initiated, and it then continues in a vacuum where there is no

resistance, where there is nothing to impede the motion, or to destroy it by action in a contrary direction, the motion will be continuous and entirely uninterrupted. For there are neither centripetal nor centrifugal tendencies, that is to say, there is no force seeking the centre or flying from it, for the point does not move within any circle capable of revolution about a centre, but the very point itself is motion. In an element which consists of particles there is a centripetal and a centrifugal tendency; for this is an elementary quality, and which is the natural result of the particles of the element which flow freely one among another, consequently, since this very point itself is motion, and gives rise to motion among elementary particles, I know not whether that which moves, gives rise to that mechanism, and originates elementary motions, is capable of possessing that quality which it is about to impart. If there is any centripetal tendency, or a falling from a higher to a lower place, or an effort to reach higher parts, from the centre, then one could at once suppose that there would be a definite reason, depending on the cause itself, why the motion should be either increased or lessened; and since this is impossible, there can be no retardation, or anything to increase or diminish the impulse originally imparted.

For this point has nowhere any upward, downward, or lateral direction; place nowhere existing. The point moves in a void, but not in a place, such as it is in some elementary sphere. It does not exercise pressure upon particles, it is not carried above or below any particles, since there are no particles above which it may be said that this point or this surface is able to be carried.

It would seem that nothing could resist this point except another point, which in the same way would make its own sphere, and by its movement form a surface. And suppose one point were to come into collision with another—if such a thing could happen—then the one would be able to move the other. Although this point which we have endeavoured to describe is not material, as we have previously stated, still it would maintain the same motion, although in the vicinity. But these things will be better seen in the following pages.

If now you prefer to say that toward one pole is an upward direction, and toward the opposite pole a downward direction, you are at liberty to do so; in the same way you might say that men in the north are in the higher regions or spheres of the earth, and those in the south in the lower regions. The matter, however, cannot be put in this way, for all who are in the world may be said to live above or below. So also here, we can speak of up and down in regard to the poles, but we cannot suppose that such is really the case; for in the sphere of this motion or activity there is no up or down.

It follows from these things that the movement of the point is continuous, and cannot be disturbed or interfered with, and that it always preserves its own motion the same, that is, that its motion is eternal; unless, in truth, it is stopped by the prime mover, God Himself. Also the magnitude of the sphere remains always the same, is always identical in form and motion, and in respect to all these things has a kind of perennial nature.

11. This movement of the point cannot be designated either motion or rest; but it has something common to both.

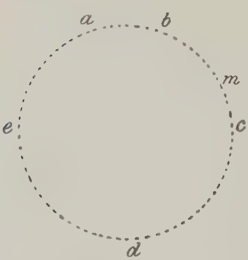
This movement proceeds in a vacuum where there is nothing but primary points driven by a continuous and infinite motion, whence it cannot be said that it is either up or down, consequently there is nowhere any place or space. Since, therefore, the movement proceeds under such circumstances, I do not know whether this should be called motion. Motion has relation to neighbouring bodies, to particles moving about one another, and to the place in which it is moved. Consequently, in this respect, it can be scarcely related to such motion as takes place elsewhere in an element. It cannot be said to be either up or down, but the term movement can be used in regard to the definite surface of the sphere which it describes. Hence, although in comparison with the motions which take place in a elemental place, it must be designated motion; still if such motion be abstracted, it would scarcely deserve the name of

motion, whence it has something common to motion and rest. Nor can it be likened to anything else than the motion of the surface of our earth, when each day it moves round from west to east. If the inhabitants of the earth can, in a single minute, be moved a distance of from six to seven hundred ells from west to east; so also round the sun, along the ecliptic; also this moving point can be said to be moved, although in a certain respect it may be considered at rest. The inhabitants are in a state of rest here, although they are borne along with an exceedingly rapid motion. We are at rest in an element, of which Newton and others have most ably treated.

12. A SINGLE POINT CAN OF ITSELF GIVE RISE TO A SURFACE; SO ALSO SEVERAL POINTS TOGETHER, IF THEY MOVE IN THE SAME CIRCLE AND IN THE SAME WAY.

How a single point by its continuous and very rapid movement can mark out a definite surface, has been sufficiently stated above already, so that it would be superfluous to add anything further. But if it should happen—whether this can be the case, I wish to explain more fully in the following pages—that several points are moving in the same circle and keep the same path, then they could also give rise to that very surface, and almost in the same way; nor would one point be an impediment to another. The circle and the path are described by all the points at the same time. One point follows another; the velocity of one is the same as the velocity of another; consequently none can impinge on another, and much less meet in an opposite direction; but one circle, as it were, and one chain continually describe the same path. If, for example, in fig. 13 a thousand points, or myriads of points, all moving with equal speed, describe the same circle *abcde*, then, since one follows another with equal speed, therefore, when the point *b* comes to

Fig. 13.

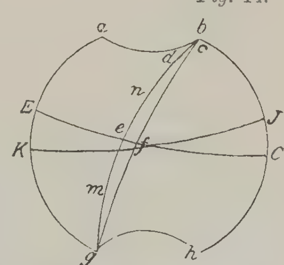


c, the point a arrives at m, and so on throughout the whole circle; the same is the case with points moving in the remaining order. When a single point moves in a spiral manner, and, therefore, with steady change of position, cuts the ecliptic or any greater or less circle of the sphere, then the rest of the points that follow do the same. It follows, therefore, that if several, or an almost infinite number of points are in one and the same circle, and are borne along in the same path in such a way, that, taken together, they form either a half or a whole circle, then one is no impediment to another, but they are capable of marking out a surface just as if there were only one point; that is, a circle of such points creates the same surface as one point taken by itself.

13. IF SEVERAL POINTS, HOWEVER, MOVE IN ANOTHER CIRCLE OF THE SAME SPHERE, IN SUCH A WAY THAT THEY CROSS THE ECLIPTIC AT THE SAME TIME, BUT NOT THE SAME DEGREE OF THE ECLIPTIC, THEN THEY CAN MEET IN THE POLAR CIRCLE, ESPECIALLY IF ONE POINT IS NEAR ANOTHER.

If two points were to move on the same surface, and each could be referred to the same centre, so that each described separately its own circle in the same surface of the sphere, it must be noted that, according to our supposition, each has the same centre, but that each describes its own circle.

Fig. 14.



If now, in fig. 14, one point were in *f* and moved from it to the smaller or polar circle at *b*, and the other point were in *n* or *m*, that is, in another circle of the same sphere, then each point would move without interference, and one would not come in contact with the other. For when the point *f* came to *b* or to the smaller circle, then the point *m*, which is in another circle, would not have reached *b*, but only *n*, and thus is at the same

distance from that point as before; nor do they approach so nearly that one in some smaller circle is able to touch, or, as it were, collide with another, but they are always separated by the same length of chord.

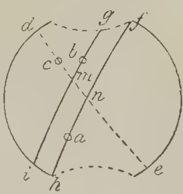
It can be seen from these things, that several, or an infinite number of points, may move in the surface of the same sphere, and, indeed, may be revolving in different circles, and yet never meet or touch, simply on this condition, that the same centre is common to all. But if one point were at *f* and another at *e*, so progressing that they cross the larger circle, that is, the ecliptic, at the same moment, the point *f* being at *f*, and the point *e* at *e*, then if they are following another closely so that they cannot be in the smaller circle at the same time, whether in *b* or in some greater circle between the polar circle and the ecliptic, one point will certainly touch another and move it from its place. This can be clearly seen, for the space in which they move will be more restricted in the smaller circle *b*, than it was in the greater circle *f* and *e*. In such case the points will come nearer and nearer together until one will push the other aside, or until all experience this and they are forced to change their centres. But, now, suppose each to cross the ecliptic in a similar way, and to cut it at an equal interval; if they are distant from one another so that in a certain smaller circle one is unable to come into contact with another, then each will be able to move uninterruptedly over the same sphere, but not so elsewhere.

14. Points having a common centre do not easily meet, but they flow uninterruptedly in the same surface; and if they do not come into contact when they have described the first circle, then they will never meet.

Because there happens to be a small eccentricity, it can, indeed, rarely happen that several points will have the same centre, and flow over the same surface] with many others round the same centre; nevertheless, if a number of points are concentric, or describe a circle which is near, or complete a circle which is

more remote or opposite to it, and if they do not meet in the first revolution, then they will never meet, but they will always be able to flow with the points of the same surface. For example, in fig. 15, let there be three points *a*, *b*, *c*, which separately describe their own circles. Let *a* describe the circle *hf*; *b* the circle *ig*; *c* the circle *de*, then, unless they meet at the points of intersection *m* or *n*, either from one direction or the other, they will never meet. If any circle cuts another, in any revolution, in two places, that is to say, on both sides of the surface, then all the points are borne along with equal velocity; one does not move more rapidly than another, consequently when the two circles meet, the points are always equally distant from one another, whichever side they come from.

Fig. 15.



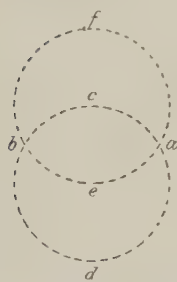
It follows from these things that innumerable points may mark out the same surface, and be carried round one centre, without one coming into contact with another. For if they were to touch one another, they would necessarily be immediately deflected from their path; this cannot take place if they move concordantly.

15. IF ALL THE CIRCLES CONSISTED OF AN INFINITE NUMBER OF POINTS, THOSE CIRCLES WITH THEIR POINTS COULD NOT BE URGED INTO THAT GYRATION OR SPIRAL, UNLESS ONE POINT MOVED ANOTHER FROM ITS PLACE; CONSEQUENTLY THEY COULD NOT MEET UNLESS THE POINTS IN ANY CIRCLE STOOD APART FROM ONE ANOTHER.

This is a result of the previous position. If the circles consisted of an infinite number of points then one point would easily touch another, or come into contact with it; for where there are many points it cannot but happen that some one of the points will touch another in its movement or course. For if any circle cuts another circle in two places, that is, in two opposite parts of the surface, so that the circles will of necessity cross each other—it cannot but happen, that, if the series contains a con-

siderable number, one will come into contact with another. If, say, in fig. 16, a great number of points move along the circle *aebf*, and also a great number move along the circle *acbd*, then, since the circles mutually cut each other in *a* and *b*, it must happen that one point will reach one of the points of intersection *a* or *b* at the same moment as another point in the circle. This would take place very frequently if the points were very numerous; but, on the other hand, if they were few it would rarely happen.

Fig. 16.



It, consequently, follows that the points will be mutually separated in their own circles, if they suitably agree. For example, let there be a hundred circles, and let each circle be traversed by its own points, then any circle will cut ninety-nine circles in two places in every revolution; or, if there are fifty circles, this will take place in forty-nine circles, or it will traverse the circles moving with it ninety-eight times. Consequently, unless the points are so situated that they in no way collide at the nodes where the circles cut one another, then they will be able to flow easily. But this cannot happen unless the points are separated by a certain distance. If this is the case, then one point can run throughout the circle connected with another point in a definite place, in which up to that time there is no point; a certain distance between the points is necessarily required.

16. IF THE POINTS ARE ECCENTRIC AND THE DISTANCE OF THE CENTRES IS EQUAL TO OR LESS THAN THE DIAMETER OF THE SPHERE WHICH IS DESCRIBED, IT MAY HAPPEN THAT ONE POINT WILL MORE OR LESS COME INTO CONTACT WITH ANOTHER; THEY ALSO MAY NEVER MEET.

From what has been previously said it can be sufficiently understood how the points flow, and how each one separately describes the surface of its own sphere. It has also been shown that many concentric points can exist and move in one surface, and that one will not move another from its place, unless they

meet obliquely, or come into collision from opposite directions. But if they move eccentrically and to such a degree that the centre of one sphere is separated from the centre of another, by the distance equal to a diameter, so that, as in fig. 17, they are in contact at the point *e*, then let one point move throughout its own circle, or throughout its own sphere, as *abegf*, and let the other point move throughout its sphere, and its own circles, as *cdihe*, then they can never come in contact. If one point is in *b* and another in *h*, the motion in each case being equal, and that distance being maintained when they are nearest together, then they cannot approach nearer. But here it is assumed that the point moving in the sphere *B*, and that moving in the sphere *A*, reaches each its own equator or zodiac at the same time, that is, *ne* or *em*. In this case they will certainly meet. For if one point moves forward throughout the equator or the zodiac in the sphere *B* from *m* through *B* to *e*, then the other point will be moved from *e* through *A* to *n*, and they will finally meet, although after several revolutions, for the point is carried round spirally. Consequently they are bound to meet, but on the supposition that each crosses its own equator at the same time. This may easily happen if there are several points which trace out the same sphere from the same point. The relation is the same if the

Fig. 17.

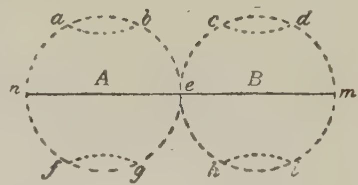


Fig. 18.

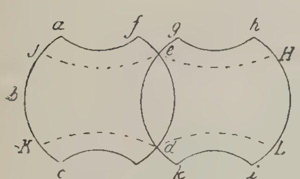


Fig. 19.

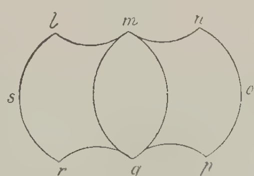
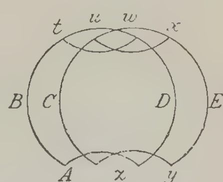


Fig. 20.



centres of the circles are distant one from another only three-quarters of a diameter, as in fig. 18, or half a diameter as in fig. 19, or a quarter of a diameter as in fig. 20, or more or less. Then

the relation is the same, provided the points meet in one circle, that is, as one point in the first sphere is in the circle *Je*, another in *eH*, or one point is in the same lower circle *Kd*, and the other in *dL*. That is to say, the points come at the same moment into those circles; then necessarily after several complete spiral revolutions they will meet, and one will displace another.

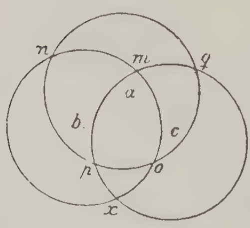
If the distance of the points is half a diameter as in fig. 19, and the points in their movement meet in the same circle, that is in the least circle of the same sphere *lm* and *mn*, then they will meet more easily still; for the smaller the circle the more easily they meet, for the space is less in which one can pass by another.

The relation is the same if the distance between the centres is still less, as in fig. 20. Then also the points will certainly meet after several complete revolutions, provided they are in the same circle, that is, if they arrive at the same moment at the same equal circle in their own sphere.

The relation is evident when a point proceeds spirally, and thus gradually moves throughout its own ecliptic; and when one point is moved from this position, the other is moved from the contrary direction, in such a way that (fig. 18) when one point passes from *H* to *Lk* in *d*, another is moved and transferred from *c* to *KJ/d*; consequently they meet in *d*, when each is moved to a contrary part.

The relation is the same if the centres are differently situated, so that if (fig. 21) the centre of one sphere is in *a*, that of another in *b*, and that of a third in *c*, then the points can meet provided they simultaneously cut the circles where these intersect, as at *n*, *m*, *q*, *o*, *p*, *x*; consequently they are bound to meet finally. And, therefore, if many points mark out one surface, as we have previously stated, the circles are bound to correspond in such a way that each point will arrive at the same circle at the same moment; the movement of each point will then be immediately disturbed, since one point must necessarily meet another.

Fig. 21.



17. Points so arranged will come into contact sometimes more frequently, sometimes more rarely.

It is quite evident from what precedes, that the points are bound to come into contact if they traverse some greater or smaller circle at the same moment, such circle corresponding to their conjunction. But as to the time, one cannot precisely demonstrate whether they will meet instantly or after an interval; retardation will depend on the distance of the point on the equator compared with the distance of another point on its own equator. For sometimes it may happen that they will meet at once; sometimes two or a hundred complete revolutions will take place, that is, two or one hundred moments may elapse before they meet. This cannot at all be reduced to calculation; for if I wished to deal with every particular, and submit everything to calculation, time would hardly permit of this. Before I submit the theory to the test of experiment, I desire to deal merely with the general argument.

Now in regard to the conjunction of lesser circles, that is, if the centres are distant one from another by any part of, but not the whole diameter, then collisions and contact of the points will more easily take place; for a point will flow through these lesser circles, and will meet and come in contact with another, which could not happen in a greater circle, for the points would pass by one another. It is, therefore, clear that the points will more easily meet when the centres of the circles are not far apart; and that they will most easily meet, if the centres of the circles are separated by only a semi-diameter. Then the circles coincide in the polar circle itself, which in respect to the remaining circles is very small. But collision will take place with more difficulty when the surfaces alone are in contact, that is when the centres are divided by a full diameter. Consequently, the periods of collision spring from the diverse situation or plane of the particles, also from the different distances of the centre.[1] All these matters you may submit to calculation if you so desire.

[1] In the margin of the MS. these words occur: "*N.B.—They do not easily meet.*"

18. Various consequences follow from the collision of the points.

There is much variety in the collision of the points. But how they meet and the nature of the position arising therefrom, can be best stated below.[1]

1. We may observe that the points flow very smoothly, and are not easily disturbed, if many are flowing round one and the same centre. Then they are so arranged with respect to one another, that about a thousand will move about their own centre, and trace out the same surface at the same time.

2. If such a surface is the result of one or several points, and all the surfaces or figures arising therefrom are mutually distant more than the length of a diameter, they will very suitably maintain their existence, and will nowhere be disturbed; for there will be no fear of collision or contact. If, however, any surface or figure is the result of several points, and are separated by a space less than a diameter, mutual disturbance will the more easily arise. For the greater the number of the points, the greater the possibility of collision, and, consequently, the greater the possibility of the disturbance of the points in the surfaces or circles.

3. If the points flow round a centre, and many such points are eccentric, then the less the distances of the centres, the more easily will they be disturbed. It has been shown above, that the further the centres recede one from another, the more easily and within a shorter time, will the points meet. The smaller the circle each one describes and the more limited the place, the more easily will contact arise on account of that limitation.

4. The aforesaid figures, that is, those which arise from the flow of the points may be in various positions with reference to one another. They may be in such a position that their centres, with respect to one another, may be in the same horizontal line, in a line forming an angle with the horizontal or perpendicular to the horizon; that is to say, one figure may be above another, the centre of one above the centre of another. Here the line which

[1] In the margin of the MS. it is written: "*N.B.—Let this be more carefully examined.*"

directly cuts the poles is called a perpendicular; the plane which passes through the equators is horizontal. It, therefore, follows that the figures may be far apart or slightly separated, and also that their centres may be respectively near to one another. Also it follows that, throughout the whole plane of the equator, as well as the plane of the poles and all other planes, the centres may have both declinatory and oblique positions; and that there may be myriads within one surface. It is evident also that an entire figure may depend on one centre only and one flowing point. Throughout the whole boundary of a single figure, it is possible that there may be centres of flowing points; it being supposed that they are so placed as to arrive at one and the same circle at the same moment; for then they are disturbed and rush into collision.

Consequently, one may conceive of these figures as if both remote and proximate in reference to one another. That is to say, myriads of such surfaces may be shut up in a narrow space, and again these myriads may be able to fill such space as can be extended and filled by them. Even if the number were increased a hundredfold or more than ten thousandfold, they could still be restricted to a narrow space, and on the other hand, the space might be vastly extended. For if a thousand points could be within the space of one or two diameters, and yet continue their own motions, and if the same points were each able to describe its own figure, were they expelled from the said space, it thence follows that the same points are able to fill, and become extended into, that vast field.

But how the figures undergo perturbation and separation with reference one to another shall be stated subsequently.

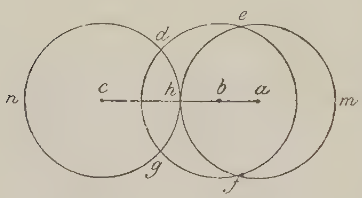
19. If the centres are slighlty moved forward with respect to one another, it then follows that all the points will be subject to disturbance, and that the figures will be rearranged.

How these figures can be moved from place to place, and mutually recede and again return, will be shown below. For

if the universe existed from such figures, and these were not bounded by their own particles and their own vortices, they would never be able to approach to, or recede from, one another, but each would remain by itself, in its own place. But since it is the vortices that bound such surfaces, and give quality to any place, they can mutually approach and recede; of which more in what follows.

Here we will merely state that all the surfaces, however many they may be, can be displaced, and all the points driven and urged into other places, provided that, as to their centres, they approach to or recede from one another gradually. For the sake of example, in fig. 22, let *a* be the centre of the figure *hemf*, and *c* the centre of the figure *ndhg*, then they meet only in the point *h*. If the points in these two figures do not all arrive at their own equator at the same moment, they will never meet. But if the figures are gradually and slowly moved forward, say from *a* to *b*, so that the figure may occupy the position *defg*, then the point of contact will be transferred from *h* to *d*, and, in the course of being transferred, the point of contact will be found at all places in the figure between *h* and *d*, and at length it will be found in *de* or *gf* as the circle to which the point of each figure arrives at the same time. For it cannot but happen that at length contacts will take place in this circle, since these points of contact move forward gradually in such a way that there is no place, or no circle, in the circumference where the surfaces are not in contact. At length, therefore, contact will take place in that circle, and at that place where both points arrive at the same moment. It follows, then, from the previous rule, in regard to collision, that one will drive another from its place; but the approach of the centres will be quite slow. The truth of this proposition stands, therefore, that if the centres mutually approach, or if

Fig. 22.



they recede slowly, it cannot but happen that one point will flow against another, and one will drive another from its place, and that then a different arrangement of the figures and surfaces will take place, or a kind of extension or amplification.

This will become the more evident if there are several such surfaces, or if there are several points in one surface; for then the perturbation will be greater, and, as it were, the force and conflict will be greater, also the changes of place and transposition.

20. If in the equator of each circle the points directly meet, no change in the figure will arise; but there will be a sudden alteration, as it were, in the same.

It is well known that, if two spherical bodies meet in a direct line, as, for example, in fig. 23, if *b* and *c* meet in this way; that is to say, if the body *c* meets the other in the direction *dc*, and the body *b* proceeds from *a* to *b*, they will come into collision in a direct line. Let the motion of both be equal, then after contact they will recede along the same line, that is, *c* to *d* and *b* to *a*. Similarly, if, in fig. 24, two points meet, as *c* and *d*; that is, if one point is carried from *i* through *g* to *c*, and the other from *k* through *f* to *d*, then they will come into direct contact in *dc*. After contact they will move in contrary directions, *d* through *f* to *k*, and *c* through *g* to *i*. No other change will take place; each point will merely be driven along the same path in an opposite direction, the surface remaining the same, and the distance between the centres of the circles continuing the same. After a few revolutions, and after a few surfaces have been described, the points will meet again, and will be again impelled in the previous and contrary directions, and so on alternately.

Fig. 23.

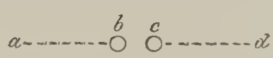
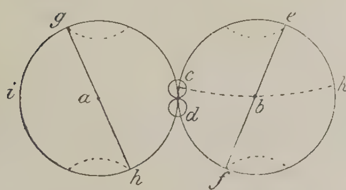


Fig. 24.



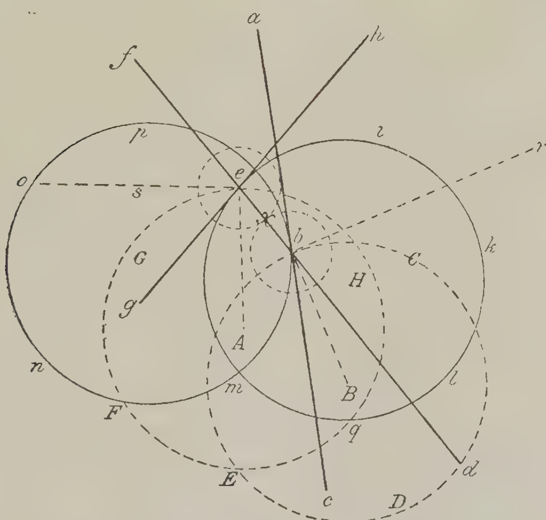
But the reason for such a sudden change in the figure will be clear hereafter. The point b of the figure is carried throughout the whole of its surface from k towards c. Similarly, when it comes to another place on its ecliptic or its equator, as in b, it will keep to the same path, that is, from b to e, and so on during its circuit. When it has thence been carried to d, that is, when it has described 180° from k, then it will continue to flow on in the same way, or from d to e to k. This flow appears to be contrary to that which it had in k towards e; still it is the same, that is, from b towards e. If now, as a result of the force arising from impact, d is carried, not to e, but through f to k, then it will appear to be moved, as though it were in k, and were carried thence to e; consequently, there is no change of figure; the flow of the point is the same, that is, it acquires the same motion by this recession as it had previously in k or at the distance of 180°. Such a change, therefore, can have no other result than a change in the same surface. Similarly in the case of the other figure.

21. If the points meet, they mutually recede according to the angle at which they meet, that is, in that direction to which the line is drawn, which is midway between the line joining the centres and its tangent.

In the previous paragraph we have treated of the points meeting from opposite directions, and of their paths after impact. We must now consider the angular direction of the points, and their paths after impact. If they meet either in direct contact or in other circles, then it is possible for them to meet in a right line or at an angle. For the points in their meeting cannot always flow in direct opposition to one another, for it may also happen that contact takes place with other points. The points must here be considered as small spheres, whose nature they imitate, because then the demonstration will be better. Spheres are traced out by motion alone; and if such motion forms anything, the figure cannot but be most perfectly spherical.

I now assume, but I do not yet grant, that the points copy the nature of spherical bodies. It thence follows that they are variously directed according to the impact of the points that meet one another; and thus according to the rules of mechanics which are similarly obeyed in regard to other spherical bodies. That is, if the spheres meet directly or at an angle, each preserving an equal and similar motion, then the points are carried

Fig. 25.



to that part whither the line is directed, which is midway between the line joining the centres and the tangents.

Let fig. 25 be considered. The circles in which the points move are *iklqme* and *bmnop*. The points are here represented as of somewhat large size, in order that a clearer idea may be obtained. Let one point be *b* and the other *e*. Let these come into contact and meet at *x*. The points can meet at other points in the circles, but for the sake of illustration let it be at *x*. If a line be drawn through the centres of the points, as *febd*, and tangents drawn to the circles, as *heg*, tangent to the circle *iklq* at the point *e*, and *abc*, tangent to the circle *pbmn* in the point *b*, then I say that by contact their flow will be deflected

in another direction. The point *b* will of itself be carried upwards along the circle *ponm*; but it is impeded by the point *e* and impelled in another direction, that is, from *e* through *b* towards *d*, or along a line passing through its centre. But since it is urged by its moving force from *b* to *a*, it consequently partakes of these two equal forces, and is borne by the resultant force along the line which bisects the angle formed between the tangent and the line passing through the centre [*ab* and *bd*] toward *r*.

Similarly, the point *e* flows along the circle *emqlk*, and collides with the point *b*. The tangent of this circle is *hg*. It has a prior motion due to its flow in the circle, or in this point along the tangent *eg*, and also a motion along the central line through from *e* to *f*; consequently, the resultant motion will be from *e* to *s* and *o* according to rule. This resultant motion in both points is equal. The parallelogram of velocities shows the paths described after impact. The motion is not greater in one than in the other point; nor is the one subject to a greater force of impact than the other. It consequently follows that the line bisecting the angle formed by the tangent and the line through the centre of the point is in each case the new path or a new tangent through which the circle then moves.

In a similar manner, if the points do not meet, but are urged obliquely, and if many are carried round a centre, and meet in a somewhat small circle in which they have not so much room as in the equator or in some greater circle, then they are driven in a lateral direction. In respect to such urging of the points in narrow circles, there is no other rule than that which we have already referred to, namely, that the flow is determined in another direction, that is, along the median line bisecting the angle formed by the tangent and the line through the centres of the points.

22. The median line along which the point recedes from its previous position is the tangent of another circle. If a perpendicular be drawn from this tangent it will pass through the centre of a new circle, which the same point describes. By such impacts circles cannot be described at a greater or less distance than a semi-diameter, unless they are moved farther from the point of another circle.

We have shown the path which the points describe after mutual impact. But since it is quite clear and evident, from what precedes, that the points cannot be carried along a right line, but in a circle and, in fact, spirally, which will be better elucidated below; therefore, when a line bisects the angle formed by the tangent and the line through the centres, it becomes a new tangent to a second circle which the points will describe, and in which they will again flow in a spiral manner. Consequently, a centre of this new sphere or this new circle can be considered.

Now let a tangent be drawn from the same place or from this new line, then the new centre will be found at the distance of a semi-diameter along the perpendicular. Let the line *br*, fig. 25, be that along which the flow of the point is directed after the impact; if from that line a perpendicular is drawn, that is, from *b* to *B*, then the centre of the new circle or the new sphere will be *B* at a distance of a radius or semi-diameter, so that the same point now describes the circle *CDE*, and marks out its sphere from the same centre; similarly, the point *e* driven by impact in the direction *so*. Since *eso* is only the tangent of a new circle, therefore, the perpendicular let fall therefrom at the distance of a semi-diameter will pass through a new centre at *A*, and the new circle or new sphere will be *HGFE*; whence the difference in the position of the point after various impacts will be clear.

Since the lines taking this new direction are only new tangents

for describing another circle from a different centre; and since that tangent is at the same point as the tangent of the previous circle; or since this new tangent is a tangent of the same kind in the same circle, therefore, it cannot be removed to a greater distance than a semi-diameter; it proceeds from the same place and the same circle. The motion is equal and all the circles arising from such similar motion have equal diameters. The semi-diameter of one circle is, therefore, equal to the semi-diameter of another; and consequently it cannot be at a greater or less distance than a semi-diameter: for the tangent of another circle is in the same place.

Still, however, they can be at a greater distance. If the points suffer disturbance again from another point in the places of impact, and are driven out by such impact, then they may again remove thence to the distance of a semi-diameter. As to the centres, they can be at the distance of a diameter, but no more.

23. The primary motion is absolute motion, and it is spiral from the centre to the circumference, so that in that motion the position of the poles is infinite and the gyration is infinite; and the motion is that pertaining to a most perfect gyration; whence must arise that other spiral motion, which has been described in the preceding pages.

In the first chapter we said that our natural principles must begin with the first point as a kind of entity; but in the same place we stated that we were completely ignorant of the state of things before the existence of the point; and that in that state there was nothing that could come under any mechanical or geometrical rules; for there would seem to have been nothing but infinite motion or infinite qualities which could give primary existence to the natural point, since there was only absolute motion, and, in fact, infinite motion, in an infinitely small place. And yet it might be justly said that I should overstep geometry and nature herself if I wished to make geometry and her laws

extend their realm there also. Geometry acknowledges nothing but what is material. One may form a conception of a point, a line, a surface, as immaterial, still one cannot connect them with things that are plainly immaterial, and still less with things infinite. Geometry is limited to the finite. But as we have stated that the natural point, whose description we have so far given, arises from a kind of infinite motion, and that the finite owes its birth to this infinite motion, therefore, our purpose is to describe in a few words the infinity of this primary motion, although geometry cannot demonstrate it.

I do not think that this motion can be conceived otherwise than as a definite, persistent gyration from a centre to a definite periphery ; and such gyration must be regarded as spiral, and as that of a spiral turning infinitely, and tending towards its own superficies. But since it must be an altogether infinite and perfect gyration, it cannot be conceived otherwise than that from centre to periphery in such a spiral gyration all possible variations exist ; that is to say, the gyration is perfectly uniform, that it possesses infinite poles, that the flow is infinitely spiral, and that at every possible distance from the centre different poles have different spiral revolutions. But because geometry does not take account of such infinite gyration, it is difficult to bring it within the compass of words, consequently we desire to present merely a kind of idea of it. It is sufficient to state that the primary motion is absolute motion, it is that of an infinite gyration proceeding infinitely from centre to periphery, and that in such motion there are infinite poles, around which, nevertheless, revolution may be predicated. This, then, is the very origin of our natural point, which we have so far in part described.

Fig. 26.

If, therefore, the motion which gives rise to the first natural point is one of infinite gyration, so that it is bound to exert a pressure on the natural point that flows in a spiral line ; then, for example, let this infinite primary gyration be likened partly to fig. 26, where there is a centre from which the revolution is carried to the periphery and from the periphery again to the centre and thus in a perpetual spiral,

we then see that the first natural point is spherical in form.

If one may enter still more deeply into the consideration of the first motion, we must conceive that this motion proceeds spirally from the centre to the circumference, so that, nevertheless, there is no point borne from the centre to the circumference, but that it is the very motion itself which traces out such spiral surfaces, and, consequently, forms the first point, which we have called the natural point. Points of two kinds therefore exist.

The first kind of point is that which naturally does not shift its centre. For if the spiral revolution commencing in the centre tends continually and with infinite motion to the circumference, and again from the circumference to the same centre, reciprocally and continuously, it follows, as a consequence, that such a point, having originated from spiral motion, rests in its own place, and that its centre is not shifted by such revolution. This spiral revolution always returns to its own centre; therefore, since there is no change or shifting of the centre, no motion round any other centre can be conceived, unless there be some impulsive force. Consequently the first point is that which does not shift its centre. This is a most natural and perfect origin.

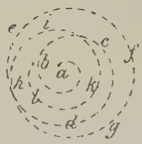
As to the other point whose description we have given in what has gone before, it derives its origin from the same spiral motion, but that motion is only slightly different; that is to say, this spiral tends indeed from the centre to the circumference, it does not, however, tend also from the circumference to the same centre, but to another centre in the vicinity, and so on continually. It consequently flows, because the centre always keeps shifting its position, and is being moved from place to place; this is the origin of the said flow of the point.

Let fig. 27 represent the first kind of point. Let the centre be at a, and consequently in the spiral from a to c, d, e, f, g, h, i, k, a, and so return to the same centre at a; consequently, such a point cannot be shifted from place to place. But in fig. 28 the centre in a is moved throughout the spiral path or superficial

spirals from a to $b, c, d, e, f, g, h, i, k, l$, and so on to the centre b, not to the centre a. Consequently, it follows that such a gyration causes a continual shifting of the centre from one

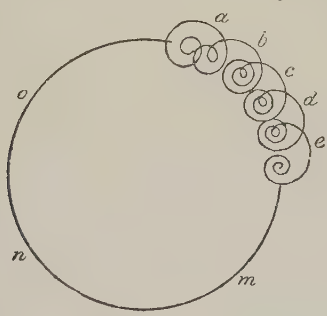
Fig. 27.

Fig. 28.



place to another, that is, from a to b, and so on perpetually; this is the origin of the natural point flowing throughout a circle. For if the centre is continually shifted, a new circle originates thence in respect to the centres, this circle being the same as the circles described from which the new surfaces arises. The flow of the natural point can be seen in some measure from fig. 29. The point of the spiral a is trans-

Fig. 29.



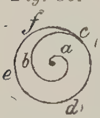
ferred to b; so to c, d, e, that is, its centre; and so by an uninterrupted flow to m, n, o; and so on, in agreement with the previous description.

As to the cause of this difference, that is, that one motion ceases always in the same point, or in the same centre, but that the other is transferred to a place always in the vicinity, no other reason can be assigned than that the gyration of one centre is less, while that of the other is greater. For, if the gyration is less, then, almost at the same moment the motion proceeds from the

surface to the centre, and from the centre thence to the circumference. But if the gyration is greater, then it does not pass back from the surface to the centre in the time taken by the gyration from the centre to the circumference. Consequently, the gyration of the surface to the centre should be finished in another centre, since it cannot return to the same centre ; for the central gyration opposes it.

It follows from these things that the points in their flow always form a certain pole ; for their spiral is a flow, and copies its own primary motion. And since the gyration from the centre to the circumference is always equal and similar to itself, and always proportionate to this motion, that is, when it reaches a certain distance from the centre, it returns again thence to the centre, and contrariwise. As there is, therefore, such an equality in this primary motion, it thence follows that the gyration in the circumference ought to be equal, since at an equal distance it comes equally to the circumference. If, in fig. 30, it begins in *a* and proceeds therefrom through the spiral to *b* in *c*, *d*, *e*, *f* and returns again in *c*, since the extent of motion is always equal, the same point will also be in *c*, from which it returns again to the centre.

Fig. 30.



It consequently follows that the superficial gyration is always the same in one point as in another ; for no difference can exist here, since there can be no difference of method and order in motion and distances. As, therefore, there is the same gyration in all the surfaces of the points, the centres cannot but be always equally transferred, and all have the same flow. Thus, poles are always formed in the same place, nor can poles be in any way moved from their positions, unless the primary motion existed in another proportion. Neither can any hindrance impede this motion : if it did, the motion would be immediately renewed, and would recover itself with the help of the primary gyration.

Here we have a spacious field for explaining the nature of this primary motion, and of geometrically elucidating this spiral. For the amount of motion can be in some measure computed

and submitted to calculation. But as sufficient material for a whole volume, and indeed much more, is involved in these questions, in regard to which geometry labours in vain, I have considered it sufficient to deal with a particular aspect of the subject—of primary origin—rather than to enter that field in which every detail and every law would have to be explained. Time would not suffice for the purpose, nor is the investigation necessary; neither do those things that follow, which it is our intention to deal with, allow it. It is, consequently, sufficient to treat the subject generally. On another occasion, by the Divine aid, if there is leisure and opportunity, I should like to add to these things.

The things adduced, therefore, in this paragraph are the same as those contained in the first paragraph. I have been necessarily led to add these things, in order that the cause might be set forth whence the motion of the first natural point originated, that is, the spiral fluxion which has its own poles, which cannot be reduced to a straight line, continually preserves its own flow, is carried with equal motion, and which cannot be arrested or diminished, that is, which cannot be caused to describe a greater or less circle. For if anything resisted, still it would be borne by the primary motion into the same circle, and, by help of the said motion, it would continue to flow on for ever and with uniformity of motion. Now we must proceed to deal with questions that remain.

The primary motion may be called the most perfectly circular motion, or the circle of circles; for in one point an infinity of circles is impelled in all directions. It may also be called the motion of motions.

24. The flowing natural points cannot be said in the primary state to be transferred from place to place.

Let the flowing points be in the primary state, that is, in the first place, let them arise from an infinite primary motion, then they cannot be transferred from place to place; for place has no existence; there is neither upward nor downward, and as yet

no vortex; consequently they cannot be transferred from place to place. Place derives its quality and nature from quarters, one of which looks to the north, another to the east; or, as in any vortex, the one looks upward, another laterally, or downward. Consequently, since nothing yet exists that tends either upward or downward, space has no relativity; and since this is the case, also no translation from place to place can be conceived. Place originates from the conception which we derive from the nature of a vortex. Since, then, no quality pertaining to place exists, place does not exist.

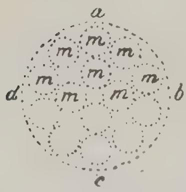
The centres of the points can indeed be transferred, in accordance with our preceding thesis; but since in this state one point cannot possibly approach another, either approximately or remotely, there cannot, therefore, be any collision. For this reason also their movement from place to place cannot be spoken of.

25. If there be a certain sphere of activity and the flowing points are confined to that sphere; or, if there be a particle to which the predicated points are confined, then they can be said to rest in definite ways, and to be transferred from place to place in definite ways.

I will briefly explain here the nature of the change of place around these flowing points. God willing, I desire to set forth the same subject more fully as soon as the nature of a vortex has been made known.

In the first place it is supposed that these flowing points are enclosed in a certain sphere, which has a motion of revolution; or that they are confined to a certain particle which revolves with its enclosed points. For example, in fig. 31, let there be a particle *abcd*, and let the flowing points *m*, *m*, *m*, *m*, be enclosed in it. (1) If the particle *abcd* is at rest, and there is no motion either round its centre or round another centre outside the circumference, then the points *m*, *m*, *m*, are said to be at entire rest,

Fig. 31.



for they experience no movement from place to place, as there is nowhere either up or down; and although they change the place of their centres, still they cannot be said to be moved from place to place, for place has, as yet, no existence. (2) If this particle or sphere revolved round its centre, still, since the points *m*, *m*, *m*, are carried along the same path and in the same revolution as the circumference, they cannot be said to be moved from place to place; for they are at rest in their own place and follow the motion of the sphere or its surface. (3) If the particle or whole sphere makes another revolution, or moves through a circle or along a right line, still the enclosed points cannot be said to be moved from place to place, for they simply follow their own particle, or their own sphere. For if the parts, or the enclosed points, follow their own sphere by any motion whatever, still they cannot be said to be moved from place to place, but the whole sphere is moved from its place. (4) But, in fact, when the sphere or particle revolves, and all the enclosed points together with the surface, then there is a certain centrifugal tendency, and also the form of a vortex. That is, if a certain point is moved forward nearer to the centre, it is immediately carried upward and from place to place. If it is moved forward toward the surface, then it is carried downward and from place to place. If a point is carried forward more simply through a circle parallel to the sphere, it is immediately borne from place to place, equally as if it moved more slowly or more obliquely.

But these things must be more adequately explained in the following pages when the nature of the vortex is first dealt with.

26. A POINT WITH ITS QUIESCENT CENTRE MAY BE CALLED A PARTICLE OF THE FIRST KIND, OR A PRIMARY PARTICLE.

We have previously described this point and shown that it originated from pure motion. Now, since this motion is a perpetual spiral gyration from centre to circumference, and back again to the same centre, therefore, a definite point arises quiescing with its centre. This is not carried into any other circle, but remains in its own place. This point cannot be truly

said to be a particle, for it is nothing but a point that has originated from pure motion. But since we have to treat of elementary particles, and this point is the primary origin of particles, therefore, in order to have a better conception of the matter and a clearer idea, this point may be designated the *Primary Particle* or particle of the first kind, not that it is truly a particle, but that it may have a definite name, and may be distinguished from all other things.

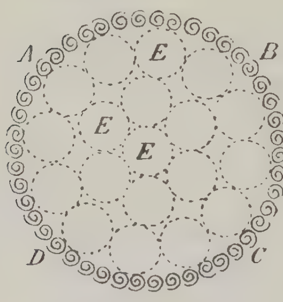
27. The particle of the second kind is the point flowing with its centre along spiral circles.

Let us call this flowing point, which has been sufficiently described in the preceding pages, a particle of the second kind, not because it is a particle, since there is nothing but a point. Still it gives rise to a definite particle by its own flowing movement, that is, a definite spherical form, which form we designate here, the *Primary Particle*, or particle of the first kind.

28. The third particle is formed, exteriorly, of points, or particles of the first kind; interiorly, of enclosed fluent points, or particles of the second kind.

As to the third particle, which may be truly designated a particle, it is composed exteriorly of points of the first kind, but interiorly it has fluent points or particles of the second kind. How the points of the first kind coalesce to form a definite surface will be shown below; but I desire merely to indicate its composition. For it is like fig. 32, where the surface *A*, *B*, *C*, *D*, consists of points of the first kind, that is, of those which are at rest with reference to their own centre. Within are enclosed the points of the second kind, *E*, *E*, *E*, which are spirally carried into circles. The position of these when moved, and their primary composition, will be seen below.

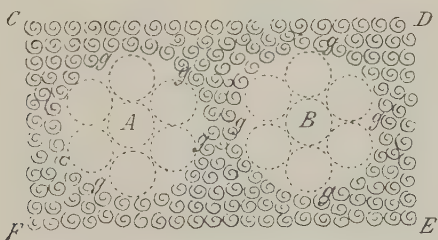
Fig. 32.



29. The fluent points at length, by their own motion, surround themselves with a surface consisting of points of the first kind.

Since the whole consists only of points of the first and second kinds, the former are at rest with reference to the centre ; but the latter change their position in reference to their centres, and, consequently, are carried through a certain circumference similar to the primary motion or spiral motion. Since, therefore, the points of the second kind are continually carried round through circles and a spiral, and nothing exists but a collection of points of the first degree, nothing else can take place but the formation of a definite surface from points of the first kind, and they will be hurried into a certain uniform motion with these included and always fluent points of the second kind. If, in fig. 33, we have a certain large space, as *CDEF*, consisting of points of the first kind, and among these also fluent points

Fig. 33.



of the second kind, as *A*, *B*, then by their own motion they will drive the resting points from them, and prepare a place for themselves among them ; this takes place naturally and mechanically. For if a certain point flows along a circle, then if anything meets it in the course of its movement, it follows that it will be driven thence ; thus that at length it will have a space in which it may freely exercise its fluent motion, as in *A* and *B*.

I might more fully prove this from geometry, but since it is

quite obvious, there is no need to waste time in useless demonstrations. Let it suffice to say that a point of the second kind will expel by its own motion a quiescent point and make a place for itself in which it will be able freely to exercise and continue its flow, as may be seen from the figure.

When, then, these mobile points have prepared a place for themselves, it is bound to happen that they will continually act against the points of the first kind, which offer an obstacle like a partition, as in *g*, *g*, *g*, *g*, *g*. When they act with a continual movement against the points which form an opposing partition, it cannot but happen that they will sensibly yield to the action, for they are passive and the included points are passive; consequently, they will be hurried by continuous action into a certain kind of motion, which is bound to be communicated to all the rest. This is the reason why definite surfaces are formed which are definitely separated from the rest, and are caused to move with the included fluent points.

From these things one may see how bodies in motion may cause other quiescent bodies to move, provided they continually rub against them. For it follows, geometrically, that a moving body will drive quiescent particles into motion provided that they are near enough to come into contact. Such particles, consequently, come into existence, as is seen in paragraph 28, where the surface consists of points of the first kind and the interior of points of the second kind.

30. THE SURFACE OF THE THIRD PARTICLE THAT HAS THUS ORIGINATED, AT LENGTH ACQUIRES THE SAME DEGREE OF VELOCITY AS THE INCLUDED FLUENT POINTS; THE SUPERFICIAL MOTION CANNOT BE MORE THAN THIS.

Since there is a continual friction and action against the particles of the surface, they are bound at length to attain the same velocity as that of the fluent points which urge them into such velocity. The motion is an impulsive one, which, if it acts against another body, causes it to have the same motion, that is, it imparts its own velocity. Conse-

quently, as the fluent point possesses almost the same dimensions as a point in the quiescent surface, the former is able easily to urge the latter into the same motion as it itself possesses, and, therefore, the entire surface.

This motion of the surface which had originated from the motion of the included points, can in no way cease; for if it were delayed or hindered for any period, yet, by the continual flow of the interior points, it would be gradually urged into the same velocity. Since, therefore, the moving force is confined within, and cannot cease to act, the motion also of the surface will be persistent and uninterrupted.

31. THE MOTION OF THE SURFACE, OR OF THE THIRD PARTICLE, IS THE SAME AS THE MOTION OF THE INCLUDED POINT, THAT IS, IT IS A SPIRAL MOTION.

This also follows from what has been previously said. For since by continuous action the fluent point impels the point quiescent in the surface, it not only must cause it to attain the same velocity, but also make it partake of the same motion. For the origin of the motion of the surface is the motion of the fluent point; consequently, it also partakes of the same motion as that possessed by those against which it acts, as well with respect to velocity as with respect to the impact, whence also there is a spiral motion in the surface.

It consequently follows that the points on the surface and the points confined in the interior share a kind of equality, and that they are so perfectly conjoined and united in a single particle that there is nothing to disturb them. Their velocity is equal, their spiral motion is equal, and there is equality in all those things which result from the motion. When a point is moved interiorly throughout its own circle, and when it touches some point belonging to the surface, then it scarcely touches it, but it always preserves the same position in respect to the intrinsically fluent point. There is then an equality, and a kind of similitude in the motions; consequently, these are symmetrical and harmonious.

32. In the surface of this impelled particle, we have polar position, an equator, an ecliptic, a uniform progression along the ecliptic, and so forth.

This follows from what we have previously stated. We have said that the motion in this third particle is the same as that in the second, both with regard to velocity and the very direction of motion. Whence it results from our preceding statements that the same is the case in the motion of this particle as in the motion of the prior or enclosed particle.

But since it is very necessary that the nature of this motion should be well understood, the subject must be more fully elaborated. We have previously stated with regard to this particle, that its surface consists of particles of the first kind, and that the motion of particles of the second kind causes a definite series of particles of the first kind to move in a similar way; for they are bound to follow the same motion. Since this is the case the flow will be entirely spiral, so that the particles drawn into that motion revolve in the same way as the fluent points, with this difference only, that in these particles the series of points follows the spiral motion, and circumgyrates uniformly, like some screw, or the motion of the heart, as it were.

It is difficult, indeed, to explain correctly the nature of this motion; it is sufficient to say that the entire surface is carried into a definite spiral, and, both above and below, leaves vacant spaces for the poles, where no point of the surface flows. In a word, this motion is similar to the motion of the point which we have described, with this difference only, that the whole surface flows in this manner; but in the case of the point, one point only moves. A conception of the nature of this fluxionial movement may be formed, therefore, from the description we have already given.

But one thing seems to be opposed to this, that, if the entire surface is urged to such a spiral gyration, it cannot be continuous and consist of continuous points. But in regard to this, I would say, that it can by no means be continuous and filled

with points, since it is in the nature of the points that the spiral motion should come from a centre and proceed to a definite circumference (fig. 34), and return again to the centre; consequently, when the spiral tends to the circumference, then it is greater and ampler; but when (fig. 35) it tends from the circumference to the centre then it is less, and more restricted. Such a point, therefore, is amplified and contracted, and expands and contracts like the lungs, or the heart.

Fig. 34.

Fig. 35.

Since then the points, of which the surface consists, are of such a nature, that they expand and contract every moment, but yet alternately, it follows, therefore, that a crowd of points in the surface does not prevent them from duly describing their own spiral; one does not act as an impediment to another.

For when these quiescent points are driven into motion by the fluent points, it necessarily follows, that they will first be driven into a gyratory movement and a kind of spiral volume, as is the case in any other element and in water itself, when urged into motion. But it proceeds gradually and by a spiral gyration, and in this gyration it can continue its own motion and preserve it perpetually.

It follows from the above that this particle of the third kind has the same motion as the fluent points, and that, like the heart and lungs, its surface infolds itself and thus undergoes perpetual changes. It also follows that the form of this particle is spherical; for the surface has a circular spiral movement, and thus is everywhere rounded up and folded upon itself.

It follows, also, that there is one polar section above and another below, in which there is no point, but which stands, as it were, open. It remains in that condition, since the enclosed points impel the surface to take up the same motion as itself, nor are they able to act toward those places where the polar sections are; for they set up the same spiral revolution, consequently there is bound to be a gap and an opening where the poles are around them to a certain distance.

It also follows that there is an equator, that is, a greater circle which cuts the particle in the middle; that there is also a zodiacal circle which cuts the spiral lines at right angles. Since there is a spiral gyration in the points, as we have pointed out, there is also this circle, that is to say, the ecliptic, which continuously but gradually shifts its points of intersection, and which has its own pole at a definite distance from the pole of the equator.

The things which have been stated in this paragraph must be considered of the greatest importance. From the above characteristic there arise then the quality and nature of the elementary particle, and many other particulars, which will be shown below.

33. The enclosed fluent points, or the particles of the second kind, follow the motion of the surface, and are forced round spirally even to the centre.

When the surface is continually moved through a spiral gyration, the enclosed points, at least those which are nearest to the surface, will be urged into the same gyration. It is in entire agreement with the rules of mechanics, that what is enclosed follows the motion of that which encloses. The cause is the continual friction and action of the enclosed points on the surface points, as well as the reciprocal action of the surface on the enclosed points; consequently, where the surface is urged into such a gyration as we have described above, it follows also that the enclosed material, or the enclosed points, at least those which are nearest to the surface, are urged into the same gyration.

There is no need to describe this gyration, for this can be gathered from the description of that of the surface. There is the same gyration in each, with this difference only, that the enclosed points are compelled to assume that gyration; for they follow the surface, consequently they are actuated by it.

For this reason the enclosed points partake of a double motion—

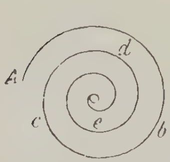
one of these we have described at sufficient length in the previous pages—that is to say, it is a motion around its own centre running out into spiral circles; the other that which the enclosed points take up from the motion of the surface. For then their centres are carried round with the whole sphere of the point; to such a degree that at the same moment the point has here a double motion, one around the centre, the other in agreement with the surface, also running out into a spiral; just as all fluids do which are enclosed within some moving body, for these partake of the same motion as the moving body, and are, as it were, set in motion by it. This motion cannot be really designated motion, since it follows the surface as that of a body definitely moved. As it follows its motion, the point cannot be said to be moved, but to be at rest in relation to this motion like something subservient. For what is moved by and with another thing cannot be said to be moved, but to be at rest in relation to the body in motion, just as is the case with the atmosphere in relation to the terrestrial globe, with which it moves daily in the rotation of the earth round its axis, and in its orbital path round the sun; and although it moves, nevertheless in respect to the moving body of whose motion it partakes, it nevertheless is at rest in its own vortex. So also the point can be said to be moved only in this respect, that it draws itself back from the motion of the surface and makes a somewhat retrograde effort. These things are said concerning the motion of the enclosed points which are nearest to the surface.

34. The enclosed points as far as the centre are together drawn into a spiral gyration; but the points more remote from the surface do not then follow or obey this motion; but gradually retract themselves, while the point at the very centre itself simply turns itself equatorially.

There is no need for proof of the above proposition; it is sufficient to regard it as a statement applicable to every fluid. For if a vessel full of water is rotated swiftly round its centre,

then the water which is nearest the wall of the vessel will perceptibly follow the motion of the surface or wall; water which is more remote will not follow so easily, and will have less velocity, and strive to return continually to its previous state of rest, or be, as it were, drawn on by water that is moving more rapidly. We therefore see in a fluid or in water a kind of spiral dragging movement; this is made clear by experiment. The same applies to the circumstances we have mentioned above. The fluent points which are around the surface are borne somewhat swiftly, for they are hurried on by the surface itself as by a stream or by some force; but the points which are more remote from the surface gradually follow and are carried round; in such a way, however, that they are not hurried on by the same motion, for the surface does not directly act against the remoter points; but the points which are nearer the surface gradually act against these, and thus draw them into a gyration and vortex, as it were; but since the force that acts is weaker, the points do not take the same fluent motion, but gradually retract themselves. From these again a kind of spiral drag of the points arises from the surface to the centre; as is the case when water enclosed in a vessel is rotated; the same takes place with every fluid, of whatever element it consists. As, in fig. 36, if A is a volume of water inclosed within any vessel, then when the vessel is rotated the water is urged into the same rotation, and draws, as it were, the interior water along with itself; but since this is driven into motion by the exterior water, it does not follow as a result of its own effort, but from compulsion, consequently that motion proceeds from the surface to the centre spirally.

Fig. 36.



As to the enclosed points, they also follow their own surface, as we have said, and indeed they partake of the same gyration as the surface; and since that gyration is spiral, according to our description, therefore also the spiral is a result of the enclosed fluid, but it slowly diminishes or retracts itself as far as the centre, so that the spiral gyration which is in the surface is, at

length, continued toward the centre, not having, however, exactly the same spiral form as that of the surface, being simpler, and, in fact, having a rotation and revolution along the circle of the equator alone.

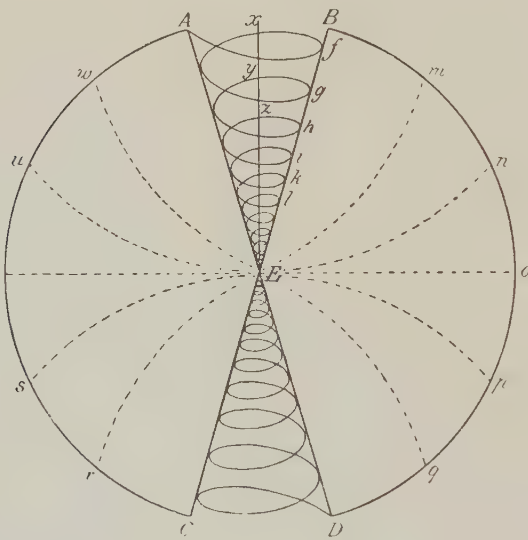
All this might, indeed, be amplified by figures and demonstrations; but it is sufficient that it agrees with experience and geometry, that the enclosed points should perform their revolution according to the gyration of the surface; but since that force is diminished, so also is the motion itself, which ends in the simple revolution in the centre. This can be proved not only in the case of water; but also in any other way. As for example, if rather long paper strips, or any other filaments that easily yield to the air, be fastened to a stick, then, when the stick is moved about in the air so as to impart a kind of spiral gyration such as we have spoken of, then the external part forms an exact spiral, in agreement with the manipulation and vibration of the stick; but the strips or threads which are in the centre are not twisted into the same spiral, but partake of a simpler motion, that is, a simpler movement of revolution.

If, now, you consider that the force of the flowing movement throughout spiral circles from the surface to the centre is gradually diminished, it follows, consequently, that, with the diminution of that force at the centre, the power of turning itself to the same spiral is diminished, the fullest action in this spiral gyration being in the greater circle. This action, as being very great and very strong, is exerted against the sphere at the centre; on the other hand, those actions being weaker that take place in smaller circles are gradually diminished, and at length vanish toward the interior parts and the centre. It therefore follows that the point flowing at the centre is urged only by the maximum force at the surface—which acts along the greater circle—that is, into a revolution along the equatorial circle.

35. THE FLUENT MATTER THAT ENTERS DOES SO THROUGH POLAR CONES AS FAR AS THE CENTRE, AND REMAINS IN THE CENTRE.

In order that the theory above stated may be the better comprehended, consider fig. 37, which represents a particle of the third kind, a description of which we have already given. The superficial points lie in the surface *B*, *m*, *n*, *o*, *p*, *q*, *D* and in *C*, *r*, *s*,

Fig. 37.



t, *u*, *w*, *A*. Upon this surface the points referred to flow, and are carried round in a spiral gyration; and by such flow they form that surface and the minor circle in *AB*, or the polar segment in each direction; for the points cannot flow into the parts *AB* or *CD*, as we have before stated; they can flow only in the given surface.

Since the enclosed fluent points are urged by the same gyration from the surface to the centre, and since the motion toward the centre is retarded, then the following can be seen from the figure: (1) The form of the surface which the flow of the points describes;

(2) The polar gap, which ends in a kind of cone pointing to the centre from both directions; (3) It can be seen also that the motion at the centre ends in an equal and more simple motion, in agreement with what has been stated in the preceding paragraph. For the circles *fghiklE* are merely circumferences which drive the enclosed points from the surface to the centre in the wall of the cone; not, however, in the very body of the cone, only against its walls; for, in this wall, the points turn toward the centre; and this spiral vanishes in the centre and ends in a steady motion. For as the cone becomes narrower, so also the spiral circles become contracted, and, finally, terminate in an exact circle. If, then, any points, either of the first or second kind, enter that cone, so as to be near its walls, then, on account of the spiral gyration, they are deflected from the surface *A*, or the surface *B*, toward the centre, by following the deflecting stream. For that spiral stream is bound to arrive at the centre; whether it comes from *A* or *B*, *C* or *D*, it does not cease until it comes to the centre *E*. When, now, it does reach the centre *E*, then it cannot possibly pass back again to the centre—for the gyration takes a contrary direction—but it either remains in the centre, or flows thence from *E* to *m*, *n*, *o*, *p*, *q*, *r*, *s*, *t*, *u*, *w*, etc.; so that it cannot return from the centre through the poles, but must inevitably pass along a definite diameter from the centre to the circumference; this cannot happen in the case of a particle of the third kind.

Since this particle is very small, no other matter can enter it through these polar cones, but such as is similar to the matter which is either in the surface or is enclosed in it. If the points are of the first kind, when they reach the centre, they flow from the centre to the surface, since they cannot be urged into that motion together with the enclosed central point. If there be any other point, such as a fluent point, which is carried by that gyration to the centre, then, either it remains, or it is raised up to a definite distance from the centre, and there with other points causes alternations of its own motion.

36. In this particle there is something of a centripetal and vortical nature.

In regard to the centripetal and centrifugal tendency involved here, I merely desire in this connection to examine the reasons and the mode; but when it comes to the larger vortices, I think I shall be able to show with sufficient clearness the true reasons and modes. But in regard to this particle, since it circumgyrates with a continuous motion, and the enclosed points are moved with the surface, and that motion is continued to the centre; it is, therefore, bound to have a kind of centripetal tendency; for unless this were the case, the particle could by no means subsist and continue its own motion. On this characteristic depends the completeness and continuance of the particle, together with the various equalities and similarities of its motion with neighbouring particles.

Fig. 38.

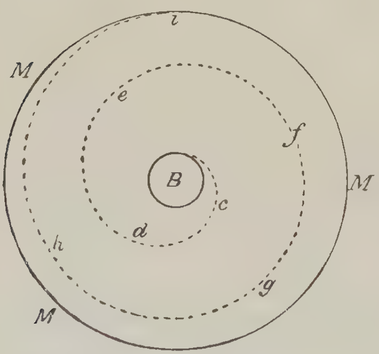
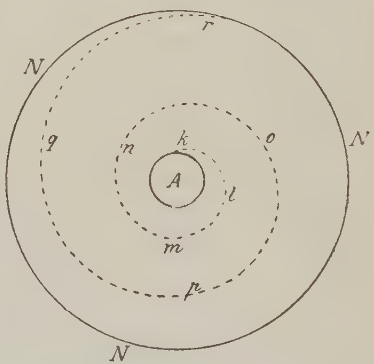


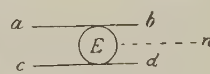
Fig. 39.



In regard to the centripetal tendency, consider, fig. 38, where the motion of the surface MMM draws the points, or, if one may use the term, the enclosed matter, into gyration, by a continual traction from the surface to the centre B. The greatest motion of the enclosed fluid is near the surface $ihgf$, but not toward the centre; for the motion of the enclosed fluid is less there, according to the figure. It consequently follows that, if certain parts come toward the centre, where they are not so forcibly impelled, they will remain there. And if they are near the surface, as in

ihgf, because they are between the points or between the particles that are driven with the greatest motion, then they cannot be impelled in a moment with the same degree of velocity as they possess; for this is bound to take place gradually. Consequently, since the motion among the particles is very rapid, they are driven toward that place which is most suitable either for their motion or rest. But as what we have said cannot be yet acknowledged as coming under geometry, consider fig. 40. Let *E* be a certain part or spherule in the sphere of the particle discussed. The motion *ah*, or that motion which acts against the higher part of this globe, is more rapid than the motion which acts against the lower part *cd*; for the motion which acts in the centre of the globe, as *E*, is so rapid that it cannot drive the globe into the same motion as itself along the same line or path in *n*; for it can come gradually into the same velocity, not immediately and at the same moment as the impulsive action takes place.

Fig. 40.



Since, then, the force acting at *E* or the middle of the spherule has no effect, therefore the motion in the higher and lower parts *ab* and *cd* is able to exercise its utmost influence; for it has the greatest obliquity, consequently it can there exert its particular force. Since, now, there is a greater motion or moving force in *ab* than in *cd*, it consequently follows that it is driven from the higher towards the lower part, that is, from *b* to *d*, and thus from the surface toward the centre. Therefore, since the greatest motion is nearest to the surface, and decreases gradually toward the centre, it is driven down by a greater motion from the higher to the lower part, that is, to the centre.

But if the greatest motion were nearest the centre; as, for example, if the centre, fig. 39, revolved, and drew with it some fluid material, in such a way, however, that its gyration or motion toward the surface became slower, or, in whatever way this took place, the motion near the centre would be more rapid than that at the surface, and a definite centrifugal effect would

arise. For the rapidity of the motion acts more at the lower than the upper part, that is, more at *cd*, fig. 40, than at *ab*, consequently it is driven, of itself, as it were, from the centre toward the surface. This will be seen to be the cause of centripetal and centrifugal tendencies.

But since there is great variety here in the central and superficial velocity, its origin and continuance, also in regard to the bodies which flow into that sphere, the lightness and heaviness of those bodies in respect to the element into which they had entered, therefore, putting aside special cases, I have chosen to deal with a certain general cause. With the varieties referred to I shall deal in the proper place.

We see here that in the particle of the third kind, a sort of centripetal tendency must arise from the motion of the enclosed fluid; consequently, it follows that a kind of vortex arises. But before this can be explained, the following particulars must be considered.

37. In this particle let there be a perpendicular from the centre to every part of the spherical surface, and a horizontal line wherever any part is carried through any circle parallel to a circle at the centre or the surface. The progression of any part along the said perpendicular, or a greater or less progression toward any definite circle parallel to the surface, when the motion is spiral, is motion from place to place, otherwise there is rest.

In this particle there is a kind of vortical nature, and it is characterised by the same feature that we perceive by actual experience and observation to exist in our greater vortex of the earth. As to the perpendicular lines, and as to the necessity of their passing from the centre to the circumference, this is an evident deduction from experience. For if the motion is greater near the surface than near the centre, the body kept in that element or that sphere tends from a greater to a less velocity,

that is, it cannot be impelled in that sphere where the greater motion is, consequently it is gradually driven down to the lower parts, and indeed toward the centre. This line must be regarded as perpendicular. The direction of the action is from the circumference to the centre, and wherever a circumference exists; and since the action is the same, the striving toward the centre is the same. The degrees of velocity are diminished from the surface to the centre and almost equally throughout the whole circle, unless some difference exists, of which we can speak better below. Consequently, there must be formed a conception of place to place when there is a transference from a sphere of greater velocity to a sphere of less velocity—for heights and positions are distinguished by velocity of motion. But since one particle follows partly a definite circle, falling perpendicularly, therefore it is also carried somewhat along the circle, and in fact, describes a curve before it touches the centre; but, as to comprehending this, it can be spoken of only as a kind of perpendicular; for that which is carried along a circle with the sphere is not motion to a place, but is something lying quiescent in a fluid.

The same reason applies to a horizontal circle when the altitude is the same; but yet in a circle of the same altitude a body is carried around the centre. It cannot be said to be a circle in respect to the perpendicular lines, but a line always perpendicular, although actually it is circular.

In paragraphs 24 and 25, we have previously said, indeed, that if a body or some particle follows the stream of gyration, there is no motion—but rest. As for example, if a certain small body were floating in a circle remote from the centre, so far as to simply follow the stream of motion, moving neither too slowly nor too swiftly, it must be conceived as something lying at rest in the bosom of its own motion, like sailors in a ship, a child in the womb, and the inhabitants on the earth, although the body actually is carried round in a horizontal circle or in some other course. But since it is not moved of itself, but with and by another body, therefore it ought to be said that there is rest in the body moved.

But, in fact, if it follows somewhat more slowly, or is borne along more rapidly than the volume of the circle in the sphere, then forthwith it ought to be designated motion from place to place; for the body is urged beyond or within that circle or movement of the sphere.

38. The primary or superficial particles are also carried to the surface of the polar cones.

Let us consider the figure (37) in paragraph 35. I say that the superficies *Bmnop* can be carried to the superficies of the polar cone, as in *fghikl*, as far as the centre *E*. For if interior or included matter is wanting, so that in consequence the superficies must be compressed and describe a smaller circle, then the superficial matter will be carried to those parts where there is a place for it, that is, to the opening of the cone *fgh*. For *mB* is continuous with *fg*, nor can it be carried elsewhere, because on account of the motion it cannot be broken up, but is extended to the walls of the cone, where there is still an opening, as it were.

The reasons for this can be easily given. One is that the interior surface of the cone adheres to the surface of the particle; consequently, it is bound to follow that it will be carried, either by compression or contraction, to the wall of the cone. Another reason is, that the motion *f* to *A* is almost equal to the motion of the surface. When the motion is equal, the particle in the surface can partake of that motion, and find, as it were, its own analogue; but still, it does not advance farther into that cone or its wall than the force of compression requires; for it does not advance as far as the centre, unless the matter is heavier, and, adhering to the walls, acquires a certain centripetal tendency to one side. But indeed, as soon as the particle is expanded, the surface is again restored, and returns from its own cone.

39. The matter at the surface can be whirled as far as the centre near to the walls of the polar cones, that is, from both directions.

If there is a greater compression or contraction of a particle, then, for the same reason as that given in the preceding paragraph,

it may be still further whirled toward the centre. The surface is still contiguous by means of the walls of the cones as far as the centre; but still, it does not tend thither by its own effort, but on account of the contraction and compression of the surface.

40. THE CENTRE MAY INCREASE CONSIDERABLY FROM THE SURFACE MATTER, AND THUS THE PARTICLE BE CONTRACTED AS TO ITS SURFACE.

Since, therefore, the surface, by a continual flow from the circumference through the surface of the cone, is able to penetrate as far as the interior, it consequently follows that, if the force or the compression or the ejection of the enclosed matter is greater, the surface can penetrate as far as the centre, to such a degree, as to be drawn to the centre by an almost continuous nexus. Further, the compression or ejection of the enclosed material still proceeding, the surface will be still more forced to the centre, whence a kind of new centre, or an aggregation around the centre, will arise. For if a large part of the surface be driven down thither, the centre will at length have a greater and greater accretion. This is the reason why there is a very great contraction in the primary particle; for the surface is borne to the centre, and there forms itself into a kind of globe.

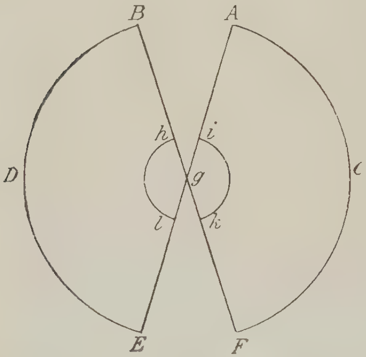
41. IF THE SPHERE AT THE CENTRE IS SOMEWHAT SMALL IT WILL BE CARRIED ALONG THE EQUATOR AS THOUGH ROUND ITS OWN AXIS; BUT IF SOMEWHAT LARGE, AND THE MATTER IS FLUENT, IT WILL MOVE VERY NEARLY INDEED ALONG THE CIRCLE AT THE EQUATOR, BUT STILL THERE WILL BE SOME STRIVING OF THE MOTION TOWARD THE POLAR SEGMENT.

If this small central sphere which has been formed from the surface matter inflowing through the polar cones, consists of fluent matter, as in this third particle, as it cannot but be—for no other matter is yet in existence—then the small central globe, arising from influx through the poles, consists entirely of fluent matter. Since then, it is fluent and the same as the surface

matter, it is bound to copy that motion which it had originated in its own place. But since the motion of this small sphere must necessarily be altogether central, let us, then, consider the origin of its motion. Consider fig. 41.

Suppose the central sphere has increased to the size indicated in the figure, in respect to the surface, *iklh*. The motion of the centre or smaller particle in the centre has previously been described, and shown to be along the equator; but if this centre increases and becomes greater as in *hikl*, then it indeed moves along the equator, since the surrounding matter does not follow the motion of its own surface, instead of that of the surface of this small sphere. For it gradually withdraws itself from that motion into a uniform motion, along the equatorial circle, but none the less it acts upon the fluent material of which this larger small central sphere consists. Therefore, when the surrounding matter acts upon the small sphere—if this small sphere consists of fluent matter—it is bound to happen that the surface of the small sphere will, in some degree, imitate the motion of the surrounding matter, and strive to move in some spiral or in some circle through a spiral, although, nevertheless, it moves along the greater circle, that is, the equatorial circle. Consequently, there is a certain effort in the surface matter of this small sphere toward the polar cones through a slow and minute gyration.

Fig. 41.



42. As long as the effort toward the poles persists the central small globe cannot be exactly spherical, but it will be elliptical.

This follows from what has been previously stated; for if the small globe is carried along the equatorial circle, and definite surrounding matter always acts upon the surface of the globe

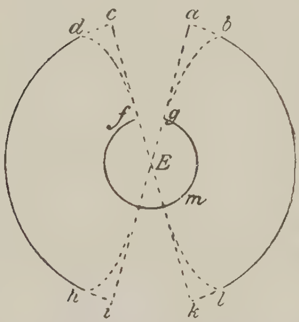
and thrusts it partly toward the globes, it follows, consequently, that part of the matter around the equator will be driven toward the poles, that is, into a kind of gyration slightly spiral. It follows necessarily that the form of the small globe will be oval, as long as the effort persists. The greater the effort, the more pronounced will be the ellipticity in a larger sphere than in a smaller one. For if the small globe be less, then it may be exactly spherical, but, if greater, then the matter forming the fluid in the small sphere will be carried to the poles, consequently there is a greater altitude there, or a greater distance from the centre. Also the larger globe becomes more oval in form; for the surrounding matter drives it somewhat forcibly into the surface of the small sphere, when that is nearer to the surface itself of the small sphere. So that if the small sphere were so ample as to make the distance between the surface of the small sphere and the surface of the globe insignificant, then the motion of the surrounding matter would act violently against the surface of the large sphere. The surface of the large sphere draws its own interior matter with itself as far as the centre; but the motion gradually diminishes in agreement with the rules laid down.

But it may happen that the sphere becomes greater, that is, that the third particle formed of fluent matter may become greater; the motion of the small sphere then begins immediately to become slower, that is, the effort toward the poles decreases. For the greater the distance from the surface of the sphere, the less does the surrounding matter act upon the surface of the globe, the spiral gyration of the surface decreasing from the surface toward the centre. Consequently, when the distance of the centre is somewhat great, that force may also be diminished, and therefore the oval form of the globe may become more spherical. The same may happen if the matter between the surface of the sphere and the globe is diminished; if, then, this matter is not sufficient, it also necessarily follows that there cannot be the same force in the surrounding matter as there would be if there were abundance of matter. For this reason, the oval figure of the plane may also become spherical.

43. WHEN THE SURFACE MATTER FLOWS INTO THE CENTRE, THEN THE FORM OF THE POLAR CONES IS SOMEWHAT CHANGED.

In fig. 42, let the polar cone be either northern or southern as *caE* or *ikE*. When, now, the surface matter flows in, then the form cannot continue to be exactly that of a cone, but the opening of the cone will be expanded so as to take the form of a hyperbolic curve. Let this be *bgEfd*, or on the other side *Elh*, having a trumpet-like form—for the matter acts from the surface as far as the centre. Hence there must necessarily be a certain curvature in *b* or in *d*, which according to calculation is a hyperbola.

Fig. 42.



But when there is no inflow from the surface to the centre, which happens when this sphere is in no way contracted, but maintains its original amplitude and dimension, then the form of the cone is represented by the surface toward the centre.

44. THE SURROUNDING MATTER, OR THAT WHICH IS ENCLOSED IN THE SAME WAY BY THE WALLS OF THE POLAR CONES, MAY FLOW TO THE CENTRE OR TO A CERTAIN DISTANCE FROM THE CENTRE.

The enclosed matter has the same flow round the polar cones; for the motion of that matter is the same as the flow of the surface matter, with this difference only, that it is gradually diminished toward the centre. And since the motion is the same, and there is great compression, therefore this also may extend to the poles, and follow in the same direction as the surface material. The cause and reason is the same for both.

45. THE HEAVIER MATTER SEEKS THE CENTRE AND THE LIGHTER THE SURFACE, WHENCE THE SPHERE IS DIFFERENTIATED IN SUCH A WAY THAT THE HEAVIEST MATERIAL SETTLES AT THE CENTRE, WHILE THE LIGHTER GRADUALLY RECEDES FROM THE CENTRE.

This is a result of what has gone before. Heavier materials seek the centre for there is a centripetal tendency, while the lighter materials seek the surface. This, indeed, is not a matter of chance, since this sphere or third particle consists of two kinds of particles, that is to say, of those which lie in the surface, and those which are enclosed within. It is clear enough from what has gone before that the heavier materials seek the centre. If the lighter enclosed matter insinuates itself through the spirals of the cones toward the interior globe, it is bound to go to the surface of the globe, because the matter is lighter; it cannot penetrate to the denser parts. Thus the difference between the lightness of the materials is proportional to the distances from the centre.

But it is not worth while to treat this point further; what we have said is sufficient in a general way.

46. THE POLAR CONES MAY ALSO BE FILLED WITH FLUENT MATERIAL.

The polar cones open out considerably, and have sufficient space, so that some matter can have place in it, consequently it can be entirely filled with matter. But that the matter, or that which is enclosed in the sphere, is fluent, will be shown below.

47. THE MOTION OF THE MATTER IN THE POLAR CONES IS A SPIRAL MOTION ROUND THE AXIS TOWARD THE CENTRE, WHERE IT IS TERMINATED IN THE CIRCLE WHOSE DIAMETER IS PERPENDICULAR TO THE AXIS OF THE POLE.

Let figure 37, in paragraph 35, be consulted. Consider the motion of this spiral sphere; first the motion of the surface, which is deflected round the poles, and thus reciprocally brings its own

deflections into the form of the spiral first described ; and understand that the enclosed matter in a kind of helix, as far as the centre, is drawn into almost the same motion, that is, it is drawn from the circumference into a spiral in almost the same, but a slower way, then it evidently follows, that the deflected matter both in the surface and within is transmitted to the walls of the cones *f*, *g*, *h*, *i*, *k*, *l*, in such a way that the motion gradually decreases from *f* to *l* ; if, therefore, you examine the circles of the cone or the interior surface of the cone, it will be seen that the motion is there directed into a kind of spiral along the path of the circumfluent matter, that is, into that form which the figure in the above paragraph represents. For not only is the motion directed throughout that form, but also the velocity. The velocity is greater in the upper part than in the lower, although the revolution is more frequent.

But, in fact, round the centre the motion is not only slower, but it almost vanishes ; consequently it also follows that, near the centre, the motion is not spiral but circular, that is, it becomes a circle whose diameter is perpendicular to the axis. The truth of this can also be deduced from another manifest argument. There is the same gyration in the southern cone as in the northern, consequently, when the spiral action reaches the centre from each direction, the matter can no longer be driven spirally, but as a result of the meeting of the spirals from each direction the motion ends in a perfect circle.

48. The axis in the polar cones throughout its whole length is the seat of a centripetal tendency.

If, therefore, the motion in the fluent matter in the polar cones is spiral, but from its summit toward the centre, it consequently follows, that the motion is greatest near the walls of the cones, as around *f*, *g*, *h*, *i*, *k*, *l*, and least in the centre, that is, in the axis *xyz* ; (but it is supposed here that the whole of this cone is filled with fluent matter). Since, therefore, it is least in the axis, it therefore follows that denser material is carried to the axis itself,

for the same reason that in the sphere they are carried to the centre, where also is the least motion. Hence there is a centripetal action in the axis when anything comes into this polar cone. Here it must be borne in mind that there is the same material in the sphere itself, or in the particle itself, as in the polar cones; but there is this difference that the movement of the matter is different; it is one thing in the sphere or particle, and another in the cone, so that they differ in motion alone. Whatever heavy material there may be in the sphere tends to the centre; whatever material there is in the cone tends to the axis, the same condition pertaining in both; the difference arises from the difference in the motion.

49. In the polar cones the revolution is more rapid near the centre than at a distance therefrom, but yet the motion itself is slower.

The velocity of the motion in the cones arises from the velocity of the matter in the sphere itself. Round f, fig. 37, the flow of the matter in the sphere is quicker than round i or k; so also in the polar cone. But since the cone is narrower toward the lower parts, therefore, although the motion is slower, still more revolutions can be completed within the same time round the centre than more remotely therefrom. For example, let the velocity in the aperture of the cone, where the cone is widest, that is near f, be 100 units, ; let the velocity around the centre or about l, be 15 units a second; but let the greater circle at the aperture f have a dimension equal to 200 units, and let the circle in l be equal to only 5 units; it is required to know how many revolutions the body in motion ought to complete in l, and where the motion is slower, when in f it describes one circle, where the motion is more rapid in the ratio 100 : 200 : : 15 : 30; and when the circle in f has a dimension of 5 units, and at the same instant, with the given velocity or a slower motion, describes 30 revolutions, therefore $30 \div 5 = 6$, that is, there are completed in l six revolutions, while in f only one is described.

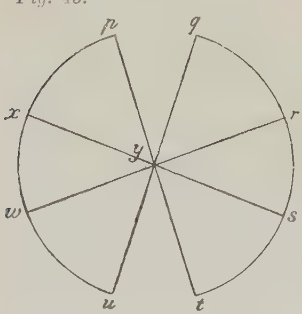
50. There is a certain centripetal tendency along the axis as far as the centre; but it is less than in the sphere itself.

Since, therefore, the motion in the cone toward the centre is slower, it follows, consequently, that there is a certain centripetal tendency along the axis at the centre; so that there are two centripetal tendencies in the cones, one from the surface of the cone to the axis, the other along the line of the axis to the centre of the sphere. But since the centripetal tendency must be considered from the velocity, and the spiral motion round the surface of the cone is more rapid than that along the axis, it will therefore be less in this direction, whence the bodies in the polar cone will proceed in the polar cone to the centre with slower motion than elsewhere.

51. A line parallel to the axis terminates in a triangle at the centre.

This seems, indeed, to involve a paradox, that is, that there is a parallelism, although the lines terminate in a definite triangle.

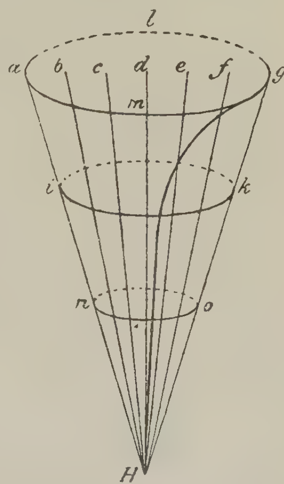
Fig. 43.



This, indeed, can be easily shown. Take, for example, the sphere, fig. 43, frequently described, *q*, *r*, *s*, *t*, *u*, *w*, *x*, *p*. All the lines which proceed from the centre are parallels, that is, all are perpendiculars which proceed from the centre to the surface, and in that respect are reciprocally parallel, as *yq*, *yr*, *ys*, *yt*, *yu*, *yw*; although, therefore, the lines in that sphere, which, in respect to the sphere are by no means parallel, in respect to compression of the sphere at the centre they are parallel. It is similar in regard to the polar cones, as in fig. 44. Here all the lines *aH*, *bH*, *cH*, *dH*, *eH*, *fH*, *gH* must be considered as parallel. The reason is, that there is the same amount of pressure at every point of such a line. For the motion

passes by spiral circles from the aperture itself to the centre, as in *algm*, or *ik* or *no*. The extent of motion from the circumference toward the axis is proportional, so that if a line falls in the third part of the circle *ag*, it also falls in the third part of the circles *ik* and *no*; and there is the same amount of motion at the same distance from the periphery, although it is slower in proportion as the circle approaches nearer to the centre. Consequently, as there is a proportionate amount, and the line passes directly through that extent of motion or those points, therefore they must be considered, in regard to the pressure, to be at the same time parallel and perpendicular.

Fig. 44.



52. A HEAVY BODY IN THE POLAR CONE FALLS TO THE CENTRE ALONG A PARABOLIC LINE; AND A LIGHT BODY ASCENDS BY THE SAME LINE.

Let fig. 44 in the preceding paragraph be considered. According to the previous statement, it is clear that there are two forces in the polar cone, one from the circumference of the cone toward the axis, which is the greatest, and the other from the aperture towards the centre, parallel to the axis. Since, then, there are two forces, and one acts more strongly than the other, therefore the path along which the body falls or ascends is a curve, that is, from *g* towards *H*, along the path there indicated.

53. THE LIGHTER MATTER SEPARATED FROM THE CENTRAL GLOBE CAN BE CARRIED TOWARD THE SURFACE OF THE SPHERE, BUT NOT BEYOND THE SPHERE EXCEPT THROUGH THE POLAR CONES.

Let it be granted that the lighter matter has followed the heavier to the centre or to the central globe, and that thence it

was separated either by motion or by any other cause whatever, then it proceeds from the surface of its globe into the sphere itself; but it cannot penetrate deeper than to the surface of the sphere. For there the matter is extremely light, and cannot pass through the surface since, this being unbroken, there is no passage. But if it proceeds from the central globe into a polar cone, then the surface offers no resistance, nor is the motion urged in a contrary direction, as in the sphere; hence it can easily pass through, and go outside the sphere itself. Instead, therefore, of the matter of each attenuated material passing out, there is a passage only from the sphere through one pole, not elsewhere.

54. THE LIGHT OR FLUENT MATTER ENCLOSED BETWEEN THE SURFACE AND THE CENTRAL GLOBE WILL ENTER OR GO OUT BY THE POLES, AND NOWHERE ELSE; BUT THE HEAVIER MATTER WILL REMAIN IN THE CENTRAL GLOBE, NOR CAN IT PASS OUT BY THE POLES OR BY ANY OTHER WAY.

This fluent matter enclosed between the central globe and the surface cannot be always in such abundance as to fill that cavity if the particle increases in size, nor can it be retained therein if the particle is compressed and becomes smaller. Why it may be compressed, and expanded alternately, shall be stated elsewhere. Here we shall merely say, that for whatever reason the particle is compressed or expanded, a different amount of the fluent matter will be immediately required. The enclosed matter cannot either enter or pass out through the surface, for it is evident that the matter forming the surface is continuous and cannot be penetrated. Hence it makes its exit about the centre or near the surface of the central globe to one of the polar cones; and, since it is lighter, it ascends and so is carried beyond the particle. The polar cone is always filled with the same matter as the sphere itself, but it has a motion different from the matter contained in the sphere. Hence it is able to pass easily from the sphere into the cone, that is, to similar matter; and to return from the cones into the sphere if necessary; and in this way the

sphere can be emptied or filled. When it comes from the sphere into the cone, the proportion of motion is such that the higher part outside the particle can be driven down, or enter from elsewhere into the cone, and thus into the sphere. There is the fountain and source, from which the matter flows, resembling in this respect the heart, through the ventricles of which the blood passes in and out; and the lungs, where the blood is able to pass in and out through its own minute vessels.

But, in fact, the heavier matter, which had sought the centre will entirely settle down in the small globe near the centre; for it cannot pass out thence through the polar cones or through the matter of the fluent sphere towards the surface.[1] Here, then, there is so far no heavier and lighter matter; but because the first particles here treated of are not yet compounded, it is, therefore, still desirable to explain these points, for we are here dealing with the cone generally, and the qualities of the sphere.

55. This third particle can undergo contraction and expansion, and, indeed, merely by contact with the adjacent surfaces; for there is nothing to impede such contraction or expansion, whether it be the surface itself and its texture, or the enclosed points.

These particles are bound to move about their own centre, according to the preceding demonstrations. For the fluent matter which is within continually excites motion in the surface, so that it is impossible for it to be at rest as long as the motion of the interior parts continues. For the surface is urged into the gyration referred to by primary interior movements. Since, therefore, the motion of the surface cannot cease, it cannot be prevented by any obstacle from describing its own circles. If, then, there were a definite volume of particles which could be compressed by some force, concerning which we must treat below, the motion could not cease, but would continue under any pressure whatever. But when a particle is subjected to the

[1] In the margin: "This must be examined more closely."—Tr.

pressure of neighbouring particles, such pressure causes a contraction in the particle itself.

For when a surface exerts pressure upon a surface, and the motion cannot be interrupted on account of the intrinsic force, then the particle is contracted and gradually diminishes, the convexity and sphericity being preserved. Suppose, now, that there are two equal globes or balls, of such a nature that they cannot be broken, and that these can revolve round a certain axis, in such a way that their circular motion cannot cease; if they were subjected to pressure, they would be reduced to a less diameter, the motion being still preserved. The same would be the case in the above particles whose motion could in no way cease. By pressure they decrease in size, whether the pressure be great or small.

The existence of this pressure will be easily granted, provided what we have previously stated be considered. The surface matter can pass through the surfaces of the polar cones into the interior parts of the cone, and, in fact, to the very centre, and form there a kind of central globe, so that, however the particle is compressed, the matter in the surface is not, as a consequence, contracted, but remains in its original position, being carried to the centre only through the cones, whence, granted that there is the greatest possible pressure, its own matter is, nevertheless, not compressed, but is only carried into other parts, and received there.

As to this surface matter, we have previously said, indeed, that it is carried to the centre through the walls of the cones; here, now, we need merely add that it is carried equally through both cones to the centre; for the pressure in each direction is the same. Also we must repeat our previous statement, first, that the surface matter comes into the surface of the cone, and recedes somewhat from the polar circle, then that it immediately takes up a circular and spiral motion round the cones as far as the centre. For this matter takes up another motion, just as the enclosed matter does, of which we have previously spoken. Consequently, if there is a connection from the apex of the cones to the centre, then that

part which had flowed into the cone proceeds by spiral circles as far as the centre. But as soon as the particle expands and becomes larger, that part, which is in the cone, goes to its apex, and returns into that polar circle, which pertains to the revolution of the sphere itself; hence it is urged into the same motion as the surface of the sphere. We have stated the matter in this way, in order that it may be understood how the surface matter can be carried into the cones, and, indeed, into the centre itself; and, further, how it may return again into the surface, and follow the stream of that motion. But if the continuity of the surface from the apex of the cone to the centre is broken up, then the surface matter cannot return from the centre, but will remain there.

If the particle is compressed, the enclosed fluent matter can be easily forced from its own sphere into the cones; for there is nothing to prevent this taking place, according to our previous thesis. If the surface is so subject to pressure as to drive it into a narrow place, the enclosed matter is also subject to pressure, and immediately passes into the polar cone, wherein is the same matter, only moved in a different way. So, also, if the particle expands, the matter from the polar cones easily passes into the sphere or into the interior parts of the particle.

It is, therefore, sufficiently clear that the particle is capable of undergoing pressure and becoming smaller from a small amount of friction with the adjacent particles; neither can the surface material—which is only compressed by being driven to the centre—offer any resistance, nor the enclosed fluent matter, which can very easily pass in and out.

Here, also, we must observe that if the points of the second class are subject to pressure, their centres immediately undergo contraction, and when the former pass out, they may meet according to the previous thesis, and one be cast out from one place, and another from another. If any such conflict arises, and the points cannot be urged without collision in their own sphere, they are expelled, as it were, into the polar cones, where they immediately take up another motion, and are thus driven outside the sphere.

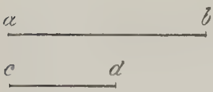
Here, too, we must observe that the included points are urged with greater motion, so that those which are near the surface betake themselves into that circle in the polar cone, in which there is the same motion, that is, the same velocity; for like betakes itself to like, and the velocity of the point into the same velocity in another place.

These brief remarks have been made concerning the contraction and expansion of this particle of the third kind. And because many things occur here, of which we have not previously spoken, therefore they will come now under consideration, as they also bear on the elucidation of what is to follow.

56. Although the particle is smaller, yet the same velocity remains in the surface; and in respect to the revolutions of the surface they are more frequent in the smaller than in the larger particle.

According to what has been previously stated, the surface is actuated by a kind of interior motion, so that it is not moved of itself, but by fluent or moving interior matter. Consequently, there cannot be a different motion in the larger particle from that in the smaller; the same velocity remains in the smaller as in the greater. Since the same velocity remains, it follows, therefore, that the revolution in the smaller particle is more frequent; just as if there were a given velocity carrying a body along the line *ab*, fig. 45, and this body were carried along the line *cd*, with the same velocity. If *cd* is half the longer line *ab*, it follows that the body will traverse the former in half the time it would take to traverse the line *ab*. In the surface of particles of this kind both greater and less, there is one equal ratio, if there is the same velocity in the greater particle, as in the less. The revolutions are more frequent in the case of the smaller particle than in that of the greater, according to our thesis.

Fig. 45.



57. The smaller the particle the greater its influence upon the central small globe.

If the particle is greater, and is impelled with the same velocity as the small one, then the enclosed matter which follows the gyration of the surface is somewhat distant from the central globe, and since the motion of the enclosed matter imitates the motion of the surface, but decreases in its gyration as far as the centre, therefore, if the surface is somewhat distant from the central globe, then the gyration, or the action upon the globe, is slower; for the spiral traction is gradually diminished.

But if the particle is smaller, and the velocity the same, according to what has been previously stated, then the space or distance is less between the surface and the globe, whence the force and action upon the globe and its fluent matter are less. It happens that the circular motion is quicker, or that more revolutions take place in the same time in the smaller than in the greater particle. Also, that the force of gyration increases from the surface to the centre, whence it follows that the action upon the central small globe is greater if the particle is smaller, than it would be if it were greater, according to our thesis.

58. The whole surface may become a kind of globe.

It has been shown above that the surface of the particle may be transferred into a kind of central globe by pressure and other causes, and that this globe may receive a greater and greater accretion. It has also been shown that the enclosed mobile matter may fly forth through the poles or polar cones; consequently, if there is much pressure the whole surface may pass into this globe, so that no surface particle remains, but only a globular one. Consequently, an exceedingly small particle may arise from a large one; for if any point of the surface whatever is almost infinitely small, then from the diameter of a particle which contains one thousand parts, a particle or globe may arise

consisting of only one part. The size of the globe depends on the smallness of the point contained in the surface.

59. THE CENTRAL GLOBE WITHOUT A SURFACE AND ENCLOSED MOBILE MATTER LOSES ITS OWN MOBILITY ; NOR HAS IT ANY BUT WHAT IT TAKES UP FROM THE MOTION OF THE NEIGHBOURING PARTICLES.

The motion of the central small globe arises from the motion of the surface which acts upon the enclosed particles, and these again upon the globe previously referred to. For there arises thence a certain motion of gyration in the matter of the small globe ; but when the cause ceases, the effect also ceases, nor is there any longer any such motion, but only that which may arise from the revolution of the neighbouring particles, which motion is entirely different from that which has been previously discussed. But concerning these things elsewhere.

It follows, consequently, that there is no longer any polar direction, that is, that there are no longer polar cones in such a particle, but that it is entirely spherical. For there is nothing to effect a polar direction ; the included matter is wanting, hence, also, there is no conical aperture of the poles, nor in any other direction, whence it is merely spherical.

60. IT WAS SHOWN THAT BETWEEN THE PARTICLES OF THE THIRD KIND MOBILE MATTER FLOWS OR PARTICLES OF THE SECOND KIND ; SO, ALSO, OUTSIDE THE PARTICLES OF THE THIRD KIND, PARTICLES OF THE SECOND KIND FLOW AND ARE MOVED.

Previously we have shown simply that particles of the second kind, which we otherwise have called fluent points, are enclosed in the particle of the third kind, and that they have their motion from these. But, in fact, there are certain spaces outside which cannot be empty. It consequently follows that these also are filled ; and that there is no other matter by which they can be filled than these particles or fluent points of the second

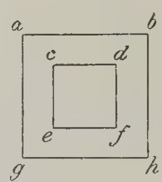
kind. These points fill all vacant spaces; for unless such spaces are filled, there would be nothing exterior to the particle. It follows, therefore, that although these points are exterior to the particle, yet they facilitate the motion of the surface, just as the interior points do.

We have also said that these have an outward and inward flow through the polar cones; whence, if the matter between the particles is deficient, it is emitted from the cones, and, if it is wanting in the particles, it is admitted through the cones; consequently new fluent matter is sought for from the space exterior to the particles of the third kind.

61. If particles of the third kind undergo contraction or dilation, still the same quantity of fluent matter is required both within and without.

The situation of the particles is the same whether there are more or less of them; hence the proportion of space exterior to the particles is the same as that within, whether they are large and expanded or compressed and contracted. Consequently, there is neither defect nor excess of the fluent particles, whether such particles undergo compression or expansion. It therefore follows that the amount of the fluent matter is always the same in the same space, unless there is some other reason why it should fly forth outside its own space, concerning which we shall speak below.

Fig. 46.



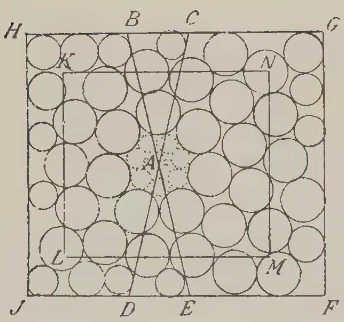
But understand that if (fig. 46), in the space *abgh* there are contracted or dilated particles, yet there is still between them the same quantity of matter; but if they are dilated, they are so compressed in *abgh* as to include only the space *cdef*, then the included matter is in great abundance, and as much as to fill . . . . . .[1]

[1] This sentence stands uncompleted in the MS.

62. The fluent points or particles of the second kind, for various reasons, may be brought together into one [place] and separately form a kind of volume, which globe can also be very greatly expanded and increased.

It is evident that there is now a universe of particles of the third kind within which and exterior to which there are fluent points, or particles of the second kind. This universe still must have its own boundaries and limits; it cannot be extended indefinitely. Or suppose it runs out to immensity or infinity, still there must be a reason why the fluent points are more abundant than those which had passed into the surface of the third particle; and this must be because there is a greater quantity of fluent points of the second kind than of the first kind. For it cannot be said that there is either equality or difference in them, or a greater abundance of one kind of matter than of another; but it will be granted that the fluent points of the second kind are in abundance either for this or some other reason.

Fig. 47.



The points certainly ought to abound if any motion has been set up between the particles of the third kind; and there is, consequently, a certain pressure between the particles. But since we have not yet any motion between these particles of the third kind but a spiral and gyratory one round the centre, we do not yet see any reason why these third particles should move among one another, and undergo a change of place; we see merely that the universe is filled with them.

Hithero nothing has been given in respect to which we can predicate altitude, perpendicular or horizontal direction, change of place, or the translation of one particle into an adjacent part;

but there is a kind of simple plenum, constant as to its particles; and this being granted, the particles are not yet compressed. Consequently they are all equal, nor does any particle yet exist which has in the centre a central small sphere, or which has simply taken a certain globular form. Since there was no reason why there should be compression, there was neither compression nor inequality among the particles.

I confess that in what I have said, I have spoken of compression and the variety of particles produced by means of compression; but hitherto I have assigned no cause for such compression; of this I shall treat below.

Let it be granted that, between the particles possessing such absolute equality, either as a result of the abundance of the points of the second kind, or for other reasons, there is a small sphere, consisting only of particles or points of the second kind as *A* in fig. 47. Let the space be small, not greater than that which would equal the space occupied by one to three particles of the third kind, and let this sphere consist of exceedingly mobile matter, or highly fluent points. Surrounding it are particles of the third kind still at perfect rest, except that they revolve spirally around their own centre, there being no motion from place to place. Since, then, there is a space between these particles, which is filled with points of the second kind, there will immediately be a primary movement amongst these particles. For they continually rub against and act upon the enveloping particles, nor do they cease so to do until they have urged them into the same kind of motion; just as took place with regard to the surface of the particle of the third kind. When they so act, they do so not only upon the particles but even upon the identical points that are between the particles. But since the narrow space is filled with these primary mobile bodies, therefore also the action and force operative upon the surrounding particles is small too. This small force draws them into a kind of gyratory movement, at first slow, then more and more rapid. When the surrounding particles begin to be moved round this given space, or around these fluent points, and the motion is altogether

similar to the motion of the surface of each particle, the points of the second kind are unable to urge the particles into any other than their own motion, that is, into the same spiral motion which has been referred to in the previous pages.

Since, therefore, the motion is spiral, the arrangement will be the same, the poles will be the same, and entrances through the cones, that is, there will be the same form of motion as there was in the surface of the third particle. Since, then, there is a spiral motion or gyration between these particles, there will immediately arise a kind of compression; one particle will press upon another; for one particle on being moved will urge another into motion. Consequently, a certain compression arises, and from compression, according to the foregoing demonstrations, a contraction or diminution of the third particle arises, that is, it becomes less. There is a greater motion near these mobile points, or near the circumference of that space in which are the points of the second kind, therefore these are compressed into a spherical form. Hence, at the middle distance they are compressed into an intermediate size, and are there particles with central enclosed spheres; at the maximum distance there is the least motion, and, consequently, the minimum of compression; consequently, the third particles remain there almost in their own form.

It has been already explained how, from the points of the second kind, enclosed in a certain narrow space, motion among the particles may exist, and, consequently, compression and diminution of the particles. From all those things that have been previously stated, it follows that the quantity of points of the second kind is more and more abundant, and, consequently, this space *A* is increased and extended more and more, and at length becomes of the greatest magnitude.

Let the space (fig. 47) *F*, *G*, *H*, *J* be filled with particles of the third kind. If, now, all these particles become less by compression, either equally or unequally according to the amount of motion, then their magnitude may become less; so that the volume of particles which previously filled the space *FGHI* now just fills the space *KLMN* or even less. It consequently follows that the

fluent matter within and between these particles, which consists of points of the second kind or of those which are in the space *A*, has not room enough between its own particles as before, and betakes itself into the space *A* either as a result of compression, or enters more remotely through the polar cones in *BC* into the central space. After the compression of the particles of the third kind this matter is abundant, and, consequently, departs thence or is left as it were derelict, and so follows the gyration of the same matter in the polar cones, and passes thither along the spiral paths.

This is the reason why the mobile sphere *A* from narrow limits increases and passes into a space which becomes greater and greater. But when the space is increased it immediately acquires a greater force, and excites motion among more particles, and to a greater distance. For if a space whose diameter is one inch, can cause a volume of one inch in diameter to revolve, a space whose diameter is 100,000 inches, will cause a volume to revolve round itself at least 100,000 inches in every direction. I have adduced this for the sake of an example, to show that that force will be increased in a greater degree than the ratio of the diameters. It will be increased more than the ratio of the cubes; on which point we shall speak elsewhere. But from these things one may conclude that from a small and insignificant origin an enormous space may be filled with this matter, or with the highly mobile points of the second kind, and thus an enormous space may be excited to motion and present in itself the nature of a vortex.

I have adduced these things merely in order that it may be understood how the first source of motion may exist in a kind of vortex, and what is the nature of that vortex.

63. The sun and stars had this origin.

It is undoubted that the sun consists of extremely attenuated matter, and that from the sun all moving bodies have their motion. According to our hypothesis, therefore, the sun could not consist of any other matter than this, of which I have given a

description in the foregoing pages. This solar ocean originated among particles in a most perfect state of rest. In taking its rise it increased and became a kind of vast sea, but not greater than its motion required, that is, to the extent to which the surrounding particles were compressed. Still, they first accumulated in one place, incited motion among the surrounding particles, and set up a gyration of a vortical nature, of which we shall speak fully below.

This solar ocean had also its own inflow, otherwise this attenuated solar matter would have flowed partly into the vortex; thence it would have flowed back again through its own two poles, so that the solar matter flowed out through the periphery into the vortex, but flowed in again through certain poles into the sun, in a similar way to that which takes place in the case of the lungs. This matter had been forced out, but it was driven in again by another way, consequently it was in a perpetual state of motion. And first, there was a kind of movement in the particles themselves, which could not cease, and, consequently, it was bound to keep the surrounding matter moving.

But as to the rest of the stars seen to maintain a fixed position in the celestial hemisphere, they seem to have originated from the sun or star of our own mighty vortex. The magnitude of this star might arise from the greater or less inflow or accretion of highly attenuated and mobile matter. But to see the reason of the diverse magnitude of the stars, consider the following. The star, or the said solar ocean, could increase only so far as there was sufficient matter.

Let it be granted that a certain sun has arisen in a certain place in the universe, it at once urges the surrounding matter into a kind of gyre, and forms a vortex; the more it increases, the greater becomes the gyration and vortex, and the greater is its acting force. Unless, then, some cause should hinder its further increase it might be vastly extended. For the greater the ocean becomes, the greater the vortex; and the greater the vortex, the more would the surrounding particles that are in

a state of motion in the vortex be compressed ; and the amount of attenuated matter flowing into the sun would be greater.

But suppose that in another part of the universe a sun or star were to originate in a similar way. This sun or star similarly forms a vortex in that place, and urges the surrounding particles into gyration. If another such star is formed at the same time, it cannot extend its vortex further than the neighbouring or lateral vortices. Consequently, the vortex being confined within limits, the compression of the particles is limited ; and also the growth of that sun or star is limited and arrested ; unless the neighbouring vortices acted as an impediment, it would otherwise greatly increase. It consequently follows that greater and smaller suns or stars would have been able to come into existence ; but each star, according to its magnitude, would also influence the size and amplitude of the vortex.

64. Such a sun or star may perish and disappear.

A sun or star may perish and disappear from two causes. One of these is that a neighbouring star may begin to increase, (whatever may be the cause of it) ; then that fluent matter always flows back again into its source or its own sun through the poles, and flows out again into its own vortex, and so on alternately and reciprocally. If, then, one star begins to increase, as stated, the attenuated matter, somewhat extended, flows into that greater source ; and, when this is increased, it acquires a greater power of setting up its own gyration, and in this way it deprives the neighbouring star of its supply of material, and, consequently, it will entirely perish as a result of the successive growth of the nearest star.

Another reason for the disappearance of a star that has once come into existence, is this : when two or more vortices are in its neighbourhood and exert pressure upon the intermediate vortex, whether it be new or old ; when an intermediate vortex is subject to pressure at the sides, matter of the third kind surrounding the star or its sun is at the same time subject to pressure, and, consequently, that matter enters through the poles into the

centre of the source, just as is the case with a particle of the third kind which assumes by pressure smaller dimensions, and sends its own matter down to its own centre, forming a kind of central small globe. A similar thing happens here. Matter by compression passes into the centre, and so the originant starry ocean perishes.

65. THE ORIGINANT SOLAR SOURCE REFERRED TO URGES INTO A KIND OF GYRE ALL THE SURROUNDING MATTER, WHICH CONSISTS OF PARTICLES OF THE THIRD KIND. THIS GYRE BECOMES GREATER AND GREATER ACCORDING TO THE INCREASE OF THE ORIGINANT SOURCE. THIS SPIRAL MOTION, HOWEVER, IS NEAR THIS SOURCE; BUT IT TERMINATES REMOTELY THEREFROM IN A MOTION ALMOST CIRCULAR ALONG THE ECLIPTIC.

Since these points of the second kind always act upon the surrounding matter, just as previously they acted upon the surface of the particle of the third kind, it is not to be wondered at that they set up in it a motion synchronising with their own, which must be that which the particle of the third kind possesses. That motion is spiral, flowing to definite poles and describing a polar circle, an equator and a zodiac. For the matter and motion in the particles of the second kind are the same, the cause in both is the same, consequently the effect must be precisely the same; that is to say, the motion will be the same in the particle of the third kind, this particle having the nature of a vortex on a small scale.

The more this mobile originant source is increased and grows, the greater must necessarily be the force with which it acts upon the surrounding matter. The greater the surface, the greater the amount of active parts in the surface, and, consequently, the greater the force acting on the adjacent matter. But the greater the distance from that source, the less is the action felt by the particles, and the more slowly are they drawn into the gyration near the originant source.

The fact that the gyration which takes place somewhat remotely from the originant source, is changed from a spiral

into a kind of circular motion, is a matter requiring a deeper investigation. Although it is not our purpose to discuss the nature and motions of larger bodies, but the geometry of elementary particles, still I will briefly show the reason why a spiral motion somewhat remote from the originant source ends in a circular motion, and, indeed, in that which the ecliptic describes.

The primary spiral motion may be seen in fig. 48, where the motion follows the curve *dcb*, and does not approach nearer the pole than *a* or *b*, so that there is a certain circle *ab* or *de* within

Fig. 48.

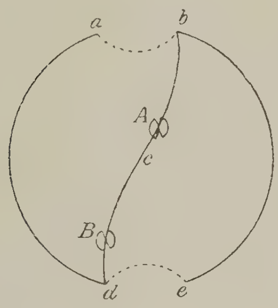
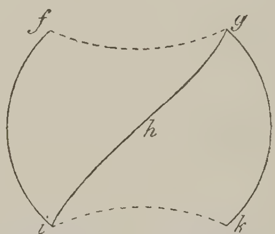


Fig. 49.



which that spiral motion does not act, but this is near the originant source. But the more remote the vortex is from that centre or source, the more does it strive naturally, as it were, to become a circular gyration, so that at a distance therefrom the gyration tends more and more to take a straight path, as in fig. 49, *ig*; therefore it approaches no nearer to the circular pole than *fg* or *ik*; and the more remote therefrom, the more does it tend to take a straight path, and the spiral traction to turn itself into a circle nearer to the equator, as in fig. 50, *onm*, so that the gyration approaches no more to the pole than is represented by the small circle *lm* or *op*. In this gyration it hastens to the end of the vortex, in which it must necessarily terminate. The reason of this is that the particles of the third kind, according to the description in the previous pages, have their own poles; that is, every particle of that kind has its own poles, and that pole always

has regard to the pole of the world, according to the demonstration in the foregoing pages. Consider fig. 51. Let *z* represent particles of the third kind. In the beginning or near the originant source, a volume of these particles is carried from *r* toward *y*, or, what is the same, from *t* toward *u*, or even still more to a perpendicular, if you prefer; but I adopt the former supposition. For, if the volume *z* were impelled from *r* toward *y*, then the particles *z* contained in that volume would maintain themselves in the

Fig. 50.

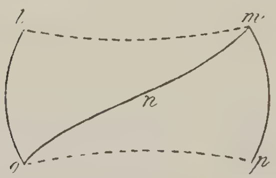
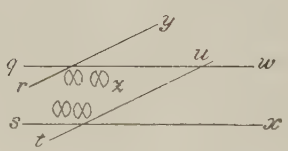


Fig. 51.



same position toward the poles as at *A* and *B*; when they pass to another part through *b*, they still preserve their own situation although they may flow in a circuit. Whence it follows that one pole will be necessarily applied to another, or that the southern pole will be associated with the northern pole of the other, either wholly or partly. This, these particles, for reasons to be adduced below, do not allow, unless they perish and are dissipated. In addition, one particle will traverse several others, and in the transit, the pole of one particle will be bound to press on the pole of another. On account of such dissimilarities, which the nature of the particles possessing poles resist (concerning this, see below), they tend to gyrate in a way which agrees better with their figure.

If then the particles *z* (fig. 51), or their volume, flow from *q* toward *w* or from *s* toward *x*, then the pole of one particle cannot possibly meet the pole of another or touch any part of it; nor can one particle be borne in such a direction across the intervening spaces of others. But if they move in the direction shown in fig. 51, as *qw*, or in fig. 50 *om*, then they will be practically carried along according to their situation; and in that motion

the pole of one will, in transit, come upon the pole of another, and it will take up a position almost like that of those particles at rest.

In a word, since the form of the particles of the third kind and their situation is according to what has been before stated, so that all the particles may have relation to the mundane pole, therefore their motion takes effect along the line in which they are situated, which is along a definite ecliptic. For it will be shown below, that the particles of the third kind can never have any polar attachment, but are only associated by a certain small circle between the ecliptic and the equator. This is the reason why, at no great distance from the originant source, the gyration thus turns itself, and immediately applies itself to the motion along a definite ecliptic; and why a gyration higher than that along the ecliptic could not proceed unless the particles were impelled by a very great motion or by considerable force. Hence the particles are naturally drawn into a gyration similar to their arrangement, and, as it were, natural to them; in which motion, too, they may be able to persist without any disruption. This seems to be the real cause of the gyration of this greater vortex along a larger circle of the ecliptic, but not along any other. These things, however, have been only briefly dealt with.

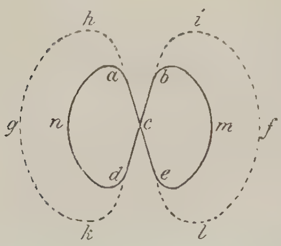
66. Around all the particles of the third kind there is a kind of small sphere consisting of points of the second kind.

It has been stated and shown above that points of the second kind are not only within the particles of the third kind, and are drawn into the same motion as the surface of that particle, but also that they are outside of it. It has not been shown, however, in what way these points flow outside the particles of the third kind. For these points are so easily influenced, that they follow the motion of another particle. They are easily drawn into that motion, so that they not only follow the motion of the

surface of the particle of the third kind within, but continue to do so because they wholly follow the motion of the same surface exteriorly; for the one is a consequence of the other. For if they follow the motion interiorly they must necessarily follow the motion of the same exteriorly. For the particles cannot have characteristics different in one place from what they are in another, provided they touch the particle or its motor surface.

It, consequently, follows that around each particle of the third kind there is a definite vortex, which almost copies the nature of the greater vortex, but nevertheless with a certain amount of difference. For example, in fig. 52, *acm* is a particle of the third kind, in which there are points of the second kind of a highly fluent nature. Exteriorly also the matter that flows between the particles is the same, and is represented by the figures *bifle*, and *ahgkd*. This matter is drawn into a kind of spiral motion like that of the enclosed matter. Since, therefore, this matter

Fig. 52.



is drawn into the same gyration as the gyration of the surface, then it cannot possibly describe any other figure than that which will be produced by the motion itself. Around the poles *ab* and *de* there is no spiral motion, it is only in other parts. But that matter flows inward and outward through the poles *ab* and *de*; therefore it cannot be in those places, but only in those that surround the surfaces; for it is drawn by the surface into a gyration. But if there were definite material around the poles *ab*, then this would be urged into another motion, whence it would be entirely separated from the remaining matter by the adjacent figure. If anything flowed into the particle of the third kind, this would take place through the poles, and along the path in *ba* or *de*; and, similarly, if it flowed outwardly. From these things it will be seen that round a very minute particle there is formed a definite vortex, which is almost a copy of the large vortex; but, nevertheless, there is some difference.

67. Whatever particles of the third kind are joined up with their own spheres, or in whatever way this takes place, they nevertheless always maintain their polar situation, nor can they be diverted from it in any way without returning to the same situation.

The action of the enclosed matter is such that it causes a spiral trend not directed to the pole itself of the particle. It would be superfluous to repeat here what has been previously stated. The surface is urged into the same gyration; and since the motion of the surface of the particle depends on the motion of the enclosed matter, therefore it is bound to be directed to the pole. And if the primary movement of this gyration and direction is in the enclosed matter, it necessarily follows that the direction is toward the pole, and that it cannot be shifted from that situation. For in whatever situation it may be, nevertheless one part looks to the pole. Action and direction are the same in the matter that is outside. Since then the impelling forces are both without and within, if their situation, previously referred to, is disturbed, they are certain to glide back again to the same position as before; so that however many such particles there are, they will all keep their vortices directed to the mundane pole; thus, therefore, they all maintain the same situation, whatever be the motion by which they may be actuated—in agreement with our theory.

68. Pole cannot be conjoined with pole except at the distance of the sphere around the pole.

There is, indeed, a reason why one particle of the third kind cannot be conjoined with another particle except round their ecliptics; on this point we are to treat in the following paragraph. But there is still another reason why this particle cannot be applied about the poles. If they were too closely conjoined round the poles, then the vortical matter of one would flow into the pole of another, and, consequently, into the particle itself, and while enlarging one it would leave the other empty. For example, in

fig. 53, if the particle C be applied to the particle D at the poles b and a, or in some other way, provided that the sphere of one particle enters into that of another near the poles, then b will be absorbed by the particle C and a by the particle D, and, consequently, a single larger particle will be formed, and the circumfluent matter will be taken from the other; and when this is the case, it will completely perish unless new circumfluent matter comes to it. Also the particle will be distended; consequently it can have no relation of motion, rest, or pressure with neighbouring particles. One, therefore, cannot be so closely conjoined with another in the neighbourhood of the poles as that the vortex of one can enter into the vortex of another. But at a distance they are capable of being conjoined, as in fig. 54, in such a way that one vortex only touches that of another. If the higher is forced downward, or they are pressed together, and one cannot yield to another, then a certain disturbance of the matter immediately takes place, and there is a disorganisation of the sphere, according to what has been previously stated.

Fig. 53.

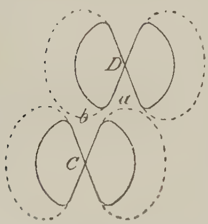
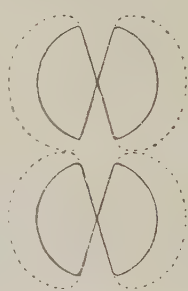


Fig. 54.

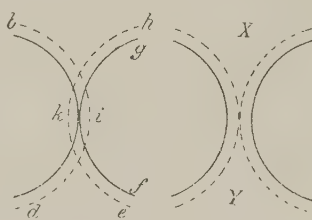


69. Particles of the third kind can be conjoined only about the ecliptics.

These particles, impelled by a steady motion, can be conjoined only on the condition that one does not delay another. For the particles are in continual movement; and motion takes place according to the laws previously stated, that is, spirally from one polar circle to another, and so on continually. It has also been shown previously, that the included matter and the non-included matter are urged into the same flowing movement as that of the surface. Since, therefore, not only the motion of the surface, but also that of the surrounding sphere, is spirally

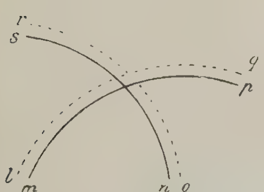
urged, they will be bound to act about the ecliptic and nowhere else. For if the spiral lines are perpendicularly bisected in the centre, the circle which belongs to the ecliptic will pass through such bisection. It follows, therefore, that all spiral lines both in the surface and in the surrounding sphere will flow horizontally or perpendicularly at the ecliptic. And since the motion is alike and takes the same direction in two or more particles, then it proceeds without any delay or any hindrance. But if otherwise then the lines of motion cannot be united, but one line will be opposite to another, take a contrary or angular direction, which at once causes a delay in the motion, disturbance in the sphere, and a lesion of the particle ; and by such opposite motion first the fluent particles are disturbed, then either scattered, or brought into order or their own situation.

Fig. 55.



For if they are conjoined so that the ecliptics of the particles just touch as in fig. 55, *ki* or *XY*, then the surface or its sphere will continually flow from *b* towards *i* and *d* ; similarly in the other part from *h* towards *k* to *e* ; consequently, they flow parallel, and the motion of one does not intersect the motion of the other either at an angle or directly ; hence they may be united in that position, or the spheres may approach somewhat closely or touch at one point. But if the motion of one intersects that of the other as in fig. 56, and *sn* cuts *pm*, then the motions of the one impedes the motion of the other. The same is the case if one particle has the position *ut* (fig. 57) and the other *wx*, then the motion of the one does not respond to the motion of the other, unless in conjunction they both have the same circle.

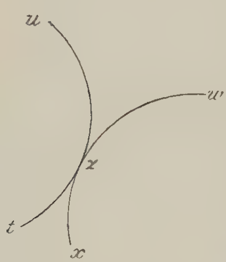
Fig. 56.



It follows from these things that, into whatever position the par-

ticles flow down, unless ecliptic is joined to ecliptic, their motion will be interfered with, nor can they be adjusted with respect to that motion unless, when conjoined, they settle down along

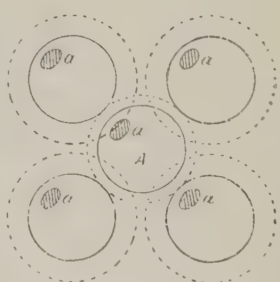
Fig. 57.



that circle, which is always capable of responding to another and of being carried in a parallel manner upward and downward. For the same reason they cannot be united along the equator, or about the poles. Whatever circle there is, the direction of motion in one particle varies from that in another, and, consequently, collisions or a kind of conflict of motions occur, which is contrary to the equilibrium of the particles.

Indeed this may be represented in a way by fig. 58. Let all the poles *a*, *a*, *a*, *a*, *a* be in a similar position; and we must conceive that they are nowhere conjoined or mutually come into contact except at the ecliptic points. In whatever direction this plane is turned, the poles will nevertheless look to the mundane pole, but they will be turned in such a manner as to be united about the ecliptic. If they were united in a different manner, conflict and opposition of motion would at once arise, which, according to geometrical laws, would

Fig. 58.



be able to completely deflect the particle, impelling and pressing it into a circle.

The distance of the adjacent particles seems to be in accordance with the size of the surrounding spheres. For if the distance were somewhat less, still it would not be detrimental, because the motion is parallel and similar. But the particle which lies above approaches somewhat nearer; still the distance of the particle which lies above and of the subjacent one is greater, so that, in fact, pole does not touch pole, nor pole rest on pole.

For the better understanding of what has been previously

stated, we shall merely add that the middle particle *A* rests on the particles below, and that there is no direct contact with the ecliptic. The ecliptic is the greater circle, for if there were contact about the ecliptic, then it would not be able to rest upon the four subjacent particles, but it would be intermediate. The meaning is as follows: that it rests parallel to the ecliptic, that is, the smaller circle is parallel to the ecliptic, which is in contact with the subjacent particles, so that it is supported by those near the parallel circle of the ecliptic. And when one of the four particles makes a transit, it does so parallel to the ecliptic, and from the smaller circle to the greater, that is, to the ecliptic, and so forth. Although the circle is less, provided it is parallel to the ecliptic, the motion is nevertheless homogeneous and similar; the parallel spirals always advance and retreat, nor does anything contrary arise in the motion.

70. The motion of the great or universal vortex proceeds along the ecliptic.

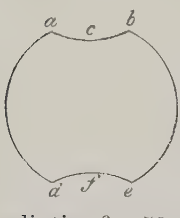
We have treated on these matters at the end of paragraph 65; but in order that a better idea may be formed, it is necessary to state the same proposition; for from the preceding statements it is clear that particles of the third kind are mutually conjoined along a definite circle parallel to the ecliptic, and that the pole of a particle always in that position looks to the mundane pole. Consequently, when a kind of vortical motion begins, it must necessarily terminate in a motion that is homogeneous with the situation of the particles. For if there were another motion, then there would be pressure according to that motion, and, consequently, the particles would be reduced to an order different from that which the motion of their surface or sphere can allow; if another, that motion would immediately offer resistance, such resistance consisting in the fact that the motion of one particle will oppose the motion of another, so that when the vortex of one comes in contact with the vortex of another, a conflict will arise from the motion of each having a contrary direction; and also there will be resistance and a consequent

lesion of the particle. If there be resistance and a resulting conflict, then, as if by a kind of force, they will be diverted into a homogeneous arrangement, that is, into one in which the motions of every particle will concur. It follows from these things that the motion of the vortex cannot terminate in any other motion than that which concurs with the arrangement of the particles; that is, a motion along the ecliptic.

71. THE ARRANGEMENT OF THE PARTICLES VARIES ACCORDING TO THE DISTANCE FROM THEIR SOURCE; THE ECLIPTIC, CHANGING THE SITUATION OF ITS OWN POLE, CONSEQUENTLY CHANGES THE POINTS OF CONTACT NOT ONLY WITH THE EQUATOR, BUT ALSO WITH THE ECLIPTICS OF THE MORE REMOTE PARTICLES. THE SAME HAPPENS IN THE MOTION OF THE LARGER VORTEX.

As to the obliquity of the situation of these particles, we must consider that there is the same obliquity in all the particles, whether they are near the centre, or very remote therefrom. The reason of this is, that the northern or polar point to which the particles look is so distant, and thence so remote, that lines drawn according to that obliquity, or along the axis of the particles, must be considered as parallel. For since there is no limit, nor is there in the universe any fixed point which may be regarded as a terminating one, but extension runs out to infinity, therefore all the particles have the same angular position, whether they are nearer the centre, or somewhat remote therefrom, near the sun, or in the extremity of its vortex. Consequently it is a sufficiently valid deduction, that all the particles of the third kind have the same angular position, in whatever part of the vortex they may be, whether in the extremity, or lower or higher. Nevertheless, this does not prevent the pole of the ecliptic from varying, and having a difference according to the distance from the centre. The pole of the ecliptic, fig. 59, must be at a point of the segment *acb* or *dfe*;

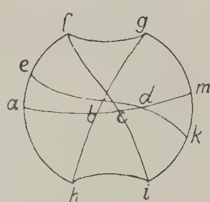
Fig. 59.



for it cannot recede remotely from the mundane pole when it traverses the circle *acb*; the pole being either in *a*, *c*, or *b*, or elsewhere; such change or translation of the centre does not vary the position of the ecliptic so far as the mundane pole is concerned. The distance from the mundane pole, the section or degree of section of the equator, and the angular position of the particles, are always the same, the only difference being that the equator is cut in another place; if the pole is transferred into another part of its own smaller circle, provided it be at an equal distance, and in the minor circle *abc* itself.

If, therefore, the large vortex had not a slower motion toward its extreme surface, but the motion were everywhere equal, then it would follow that the position of the pole of the ecliptic would be the same at every distance from the centre. But since the motion about the extreme periphery of the vortex is slower, and, near the centre more rapid, the ecliptic will necessarily alter its point of contact with the equator, or its node. For the vortex matter is continually resisting and does not easily follow its flowing movement, and only then by a kind of attraction; consequently, it is also gradually attracted from one node to another, and therefore the position of the ecliptic pole is appreciably altered. Consider fig. 60: *gh*, *fc*, *ek*, are various positions of the same ecliptic, but the pole is in a different place of its circle *fg*, let one ecliptic cut the equator in *b*, another in *e* and a third *d*, then by the stated traction of the vortex, the ecliptic will change its place in respect to the equator; still the situation of the particles in their mutual contact will remain the same.

Fig. 60.



It consequently follows that if various kinds of ecliptics are compared, one will cut another, and produce nodes. This may be easily seen by those who can use globes.

The larger vortices which float in the vast solar vortex follow this current. They follow the flow of the particles and adapt themselves exactly to their situation; nor can they depart

therefrom, since there is a definite resistance which continually keeps the floating body in a circle.

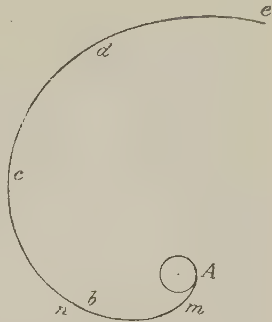
72. In the motion of the large vortex there is a certain pressure between the particles, which is less at a greater distance from the sun, and greater at a less distance.

When the particles are bounded by their own spheres, and those spheres have a very great velocity, then they are put in motion by a very slight pressure exerted by the neighbouring particles. For the nature of the motion is such that if a body of any kind comes into contact with it, a very strong pressure is exerted. For example, suppose that water is carried round with a certain gyration; if there is a similar vortex in the vicinity, then if they meet when the motion is very rapid, one will yield completely to the other. The same is the case in those particles which are enclosed in their small spheres, each one of these small spheres being driven round with very great velocity. It is not wonderful, therefore, that adjacent spheres under the influence of a very slight contact should be moved or subject to pressure; still more if the motion of both is not congruent, but conflicting. Therefore, when the large vortex is moved by the sun, it is not remarkable that those particles which are somewhat remote therefrom, should be driven into a large gyration, or should be moved by a very slight contact, and be very sensible to pressure. For the greater the velocity the greater is the sensibility to pressure or contact.

Since the source of motion is in the sun, and the motion near the sun is spiral and very rapid, one particle will communicate to another the motion it itself receives, and, consequently, one will exert pressure upon another. For example, if, in fig. 61, the source of motion is in A which sets up a gyration, then the particle in A exerts a pressure in m, and b in n, and so forth. When, therefore, the motion in A is very great, then the pressure on the adjacent particles is also very great, as at m, the velocity is greater, the number of the particles subject to pressure in the

rear, and their consequent resistance are greater. But the remoter the particles, as in *e*, the less the pressure, the less the velocity, and the less the force; for the force decreases in proportion to the distances. This does not require many words of explanation, for in every element experiment proves the same to be the case. Sound decreases in the air in proportion to the distance; undulation in the water become less pronounced in proportion to the distance; and similarly in many other phenomena. Consequently, when a certain motion is set up, the action in the neighbourhood of the motion is very strong, and, also, the pressure exerted on the same particles, such pressure decreasing more and more according to the distance. But in what ratio the pressure decreases must be stated elsewhere.

Fig. 61.



73. BY REASON OF THE AFORESAID PRESSURE THE PARTICLES OF THE THIRD KIND SUFFER DIMINUTION, THE SURFACE LAPSING INTO A KIND OF CENTRAL GLOBE, IN CONSEQUENCE OF WHICH A PARTICLE OF ANOTHER KIND ARISES; THIS IS HERE DESIGNATED A PARTICLE OF THE FOURTH KIND.

We have referred to this particle in the preceding pages, where it has been abundantly shown that the particle of the third kind can be driven by pressure to eject a portion of its surface, and drive this down toward the centre into a kind of a central globe. The particle is compressed when the vortex of one exerts pressure upon the surface of another, that is, when the particles are being acted upon in such a way that one sphere not only enters into the sphere of another, but also acts upon its surface. For if action takes place it does so near the ecliptic, whence also pressure is perceived throughout the whole surface of the particle, and, consequently, the particle forces the surface matter toward

the poles, and from the poles to the centre, according to what has been previously stated.

That a very small pressure is able to cause such diminution, has been sufficiently shown in the previous pages. But since a certain variation in the particle thence arises, it being duplicated, as it were, a portion of the surface falls into the more interior parts as far as the centre, so that this particle not only has about it its own sphere, but its surface has also a very high degree of motion, together with the sphere within, and also a kind of globe in the centre. Such a particle is a sort of microcosm; and, since it differs from the former particle, it is called a particle of the fourth kind.

74. The greater the distance from the sun or source, the smaller is the size of the central globe, and the greater the surface, and contrariwise.

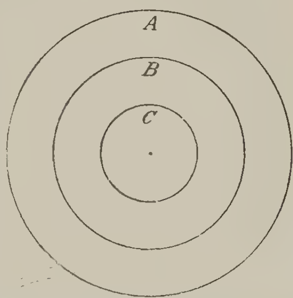
The reason of this is obvious. For the greater the motion, or the quicker the action, the greater is the pressure; and the greater the pressure the more are the particles driven into a restricted position, according to the previous paragraph. Since, therefore, the gyration is very rapid near the sun or source of motion, it follows also that the action of one particle upon another is very strong there, whence the particles are very forcibly compressed. But the pressure exerted upon the particles is not so great if they are at a distance therefrom, because the motion is less. Since the pressure accounts for the diminution of the particles or the contraction of the surfaces into a kind of central globe, therefore, according to the statement in the paragraph, it follows that the less the central globe in a particle of the fourth kind, or the greater the surface, the more distant or remote is it from the sun, and contrariwise. It may, therefore, be concluded that only the particle of the third kind is in the extreme part of the vortex, and where the vortices are in contact. In the middle of the vortex is the particle of the fourth kind, which differs according to the distances, so that the particle of the fourth kind

differs according as the extent of the enclosed globe and of the surface is small or large.[1]

75. THE SMALLER THE PARTICLE OF THE FOURTH KIND, THE GREATER THE NUMBER OF REVOLUTIONS ITS SURFACE DESCRIBES IN THE SAME TIME.

This, indeed, has been pointed out in the preceding pages. Nevertheless, it is useful to repeat it here, since this particle is now the subject treated of. The reason for the above is that there are the same motion and the same velocity in a contracted as in a dilated particle. The attenuated matter which acts upon the surface within does not cease so to act until it has impelled the said surface into a motion similar to itself. If, therefore, in the smaller surface there is the same velocity as in the greater, then the smaller surface will be bound to describe more revolutions than the greater. For example, in fig. 62, let the circle *A* revolve round its centre, and also the circles *B* and *C*; if the velocity in all these were the same, then *C* would describe more revolutions than *B*, and *B* than *A*; and the velocity remaining the same, the number of the revolutions would be [inversely] as the circumferences or as the diameters.

Fig. 62.



76. THE SMALLER THE SURFACE OF THE PARTICLE OF THE FOURTH KIND, THE GREATER THE MOTION OF THE CENTRAL GLOBE; THIS MOTION FOLLOWS THE EQUATORIAL CIRCLE.

That the enclosed small sphere is carried in its revolution along the equator has been previously shown; for the spiral motion toward the centre terminates in a kind of larger circle, that is, in

[1] In the margin of the MS.: "But this refers to the primary origin of motion, the contrary is the case afterwards."

an equator. It also happens that both the attenuated matter of the second kind, and the surface matter of the first kind flow spirally toward the centre, and that this spiral path is terminated near the central globe, whence the small globe is bound to revolve round a definite axis, which axis is formed from a spiral path terminating, as it were, in a line ; for the cone is more open above than below, and below it is so attenuated as almost to be equal to a line. Unless this motion ended in a kind of axillary motion, I am not sure whether the particles would be able to rotate in the way previously shown.

As to this axillary motion in the small central globe, it may be objected that it cannot be axillary, but must be spiral and similar to the motion of the surface. The reason may be adduced that the fluent points of the second kind continually act upon that small globe ; and that, since they act here in a similar way to their action upon the surface, it consequently follows that there is the same reason for motion in both. But to this objection it may be replied : (1) That not only the attenuated matter of the second kind acts upon the small central globe, but also the matter of the first kind, which flows in through the poles of the helix, and acts upon that small globe. (2) Not only may the attenuated matter of the second kind impinge upon the surface of the small globe, but also the very matter that is in the polar cones ; and since there is one kind of motion in the same matter in the cones, and another in the cavity of the particle, therefore these two motions form one simple motion in the small globe. (3) The globe is so small that points of the second kind cannot act upon the surface of so attenuated a sphere. The surface itself consists of points of the first kind. If some part of this surface becomes a single small globe, it cannot grow to a size sufficient for the matter of the second kind to be able to act upon it. The point of the second kind impels its own spiral fluxion round the centre, and, consequently, forms a kind of surface by its fluxion. The small globe could not attain such a size as to be able to drive a point of the second kind into a surface unless the whole surface became aggregated into a definite globular form.

If it be so small that one point is scarcely able to complete its revolution, still less so where many are concerned. It therefore follows that it is not urged along a spiral path, unless the globe acquires such a size that the fluent points are able to exercise upon it a certain force.

As to the velocity of its motion, I say that it is greater in proportion as the small globe is less, and contrariwise. It was shown in the previous paragraph that the motion of the surface is more rapid when the surface is of less extent than when it is greater. I do not mean that the velocity itself is greater, but that more revolutions are described in the same time. Also more revolutions are described in the small globe when of larger size, or when the surface of the fourth particle is of less extent. When the fourth particle is less and describes more revolutions in the same time, it follows that it will have a greater effect upon the enclosed globe; such an effect, in fact, that it will cause it to rotate many times in the same period. This also will take place along the equator according to the proposition in the preceding paragraph.

77. All motion in the surface of a particle of the fourth kind tends toward the centre and acts upon the surface of the central small globe.

There are two paths of communication between the surface of this particle and the central globe; one directly through the surface, for the surface is continued through the polar cones, or round the walls of the cones as far as the centre; the other through the matter enclosed between the surface and the globe. Any action on the surface is also felt in the globe. So that if there were an undulatory motion in the surface, it would traverse the whole sphere; for it starts in a definite place under its ecliptic and extends throughout the entire surface by means of undulation. And because the surface is continuous as far as the surface of the central globe, therefore, by means of a definite unbroken connection the motion extends as far as the centre. Also there is another path of communication through the

attenuated matter referred to, when the surface is moved in a tremulous or undulatory manner. The enclosed attenuated matter moved in the same way, extends as far as the centre and causes a certain pressure in the globe, and particularly in the surface of the globe. Probably also the whole globe vibrates or trembles in a similar manner, if it is very small, and there is no yielding of the surface.

78. THE SPHERE AROUND THE COMPRESSED OR SMALLER PARTICLE, OR THAT OF THE FOURTH KIND, IS GREATER THAN THAT WHICH ENCOMPASSES THE NON-COMPRESSED PARTICLE, OR THAT OF THE THIRD KIND, CONSEQUENTLY, IT CAN BE DEFLECTED FROM ITS OWN POLAR SITUATION AND THAT OF ITS ECLIPTIC ONLY WITH VERY GREAT DIFFICULTY.

It may be called the greater sphere in this respect that it remains the same in magnitude, although the enclosed particle is compressed and decreases in size ; for the attenuated enclosed matter is ejected by compression, and seeks an outlet for itself through the poles, whence the environing sphere is immediately increased in size, fresh matter being added from the interior sinus of the particle. In fact, the same amount of attenuated matter remains, but because part of it goes out to the exterior, therefore the diameter of the sphere becomes greater, if its diameter be considered as extending to the surface of the enclosed particle.

It follows from these considerations that this attenuated matter near the surface describes more revolutions than before in the same time. The smaller enclosed surface describes more revolutions, in agreement with what has been previously stated ; the same is the case with the sphere lying near that surface. It can, consequently, be deflected from its polar situation only with very great difficulty, because the particles are in contact along the ecliptic. For the greater the velocity in the sphere, the less the deflection of the particles into another quarter. If one particle were deflected, there would be a contrariety of motion

and fluxion in the spheres ; and, as the motion is rapid, therefore it would be immediately deflected into a parallel position, that is, where all the lines of the spirals flow in a parallel direction.

79. The central small globe remains in its own equilibrium, and must be said to be without motion, although it revolves along the equator.

Here the central small globe follows the motion of the surface or of its own vortex, but it gradually withdraws itself from the rapid spiral motion to the equatorial circle ; consequently, when it is moved with its sphere and its surface, and elsewhere in that, or in the centre of it, it is at rest, it can be said to partake of motion only in the same way as our earth daily revolves on its axis, and moves annually along the ecliptic. But we have previously dealt with these matters.

80. Near the source of motion, or the sun, the compression is still greater, and the entire surface runs off into a small globe, so that there is a small naked globe, without a surface apart therefrom ; this is the particle of the fifth kind.

In proximity to the originant source, indeed, particles having a greater expansion are found ; for otherwise the particles would be carried to the surface of this source or of the sun, and would be fluent in the element of the third kind, whence they would experience no pressure from the lateral or adjacent particles. I do not understand, therefore, those particles to be those which are in proximity to the originant source, and which are fluent, as it were, in the element of the second kind, of which the source itself or the solar globe consists ; but I speak here only of those particles which are near the source, and where one is not separated from another, but where one is in close contact with another. Here there is the greatest motion, this in fact being spiral ; and from this motion the rest of the motion in the whole solar vortex arises. Therefore, when the motion round the sun is very rapid and spiral, the particles will be bound to experience pressure, so that no surface will remain in particles of the third and fourth

kinds, but it will form itself into a small globe. There are two or three reasons why these particles suffer pressure. The first is that the greatest amount of motion exists there, and where there is very great motion, there the pressure will be very great, and, consequently, the surface will be driven to the centre in agreement with the principles established in the preceding pages; and when the force of compression is increased, the centre is bound to be increased, and the surface diminished, until at length no surface will remain; but the small naked globe will exist which is otherwise called the small central globe.

In the second place, this motion near the sun is spiral. Thence it follows that the particles are forced to follow the motion and to be deflected not only along the pole, but also in some other direction; from this mutation a kind of conflict arises in the spheres; for unless they are in contact near the ecliptic they cannot subsist. When, therefore, the spheres are so turned that they are in contact in other points besides those of the ecliptic, not only does a conflict arise but there is a dissipation of the external sphere. Hence a path to the surface being easily afforded, the sphere being removed, as it were, from opposing it, the entire surface is easily forced into a spherical form, so that it can be established that all the particles of the third and fourth kinds, which do not follow the motion of the ecliptic—for they are urged into a kind of spiral gyre—are compressed into definite small globes bereft both of their own sphere and of a surface, at a distance from the globe.

In the third place, when the surface of the fourth kind is so compressed that there is not much distance between the surface and the small globe, then the sphere of the second kind of element cannot operate either upon the surface or upon the small enclosed globe, both being so small and attenuated, that it cannot exercise its force upon either of them. Consequently, when a particle of the third kind becomes so small, it easily, and, as it were, spontaneously, passes back into a spherical form. This small globe, because it differs from the rest, is here called a particle of the fifth kind.

81. THE SMALL GLOBE OR PARTICLE OF THE FIFTH KIND IS SO SMALL THAT MATTER OF THE SECOND KIND CAN EXERCISE NO FORCE UPON IT, BUT THE SPIRAL GYRATION PERISHES WITH THE REST OF THE QUALITIES, WHICH COME UNDER CONSIDERATION WITH REGARD TO THE PARTICLES OF THE THIRD AND FOURTH KINDS.

The compression of the particles being still further increased near the source of motion, not only are the particles urged into gyration by the very great velocity, but also they are driven from the centre towards the circumference of the vortex. As to the compression which is caused by the motion of the vortex near the originant source or sun, this is bound to be so great, since the velocity is even greater near the source than near the surface. For example, let the motion of the surface near the source be 100 degrees, and the circle which it describes be 1,000,000. In fact, about the source it is 100 degrees, although it might be 10,000, but granted that it is 100, then the circle is less, nor in respect to that dimension is it greater in the circumference than in the proportion of 1 to 1,000,000. Consequently, when one particle exerts pressure upon another, the particles do not give way, as in the large circle of the vortex, where there is an abundance of yielding particles, and so facilitate the flow without much compression. For example, let there be two lines, on one of which there are ten bladders full of air, and on the other a thousand bladders also full of air; if, now, you strike the first bladder, it will communicate the impact, or its own motion, to the ten which are suspended on the line. Similarly, if one on the other line is struck, it also communicates its own motion to the thousand others suspended on the line. The motion communicated to the ten is taken up more effectively by all because the line is so short; but the motion communicated to the one thousand bladders is not taken up so effectively, because the communicated motion is distributed over them all; the perception of motion in any part whatever, therefore, is very small.

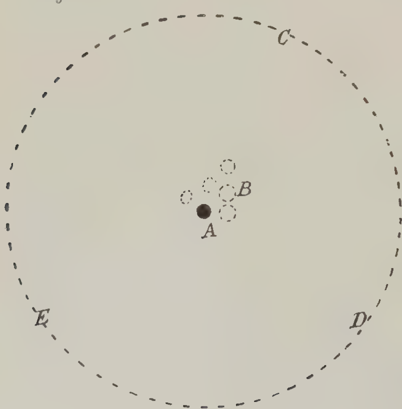
It is similar in the particles where the circle is smaller, the

motion being nevertheless proportionately great. The greater the pressure the more fully are the particles round the source of motion, or the sun compressed into a kind of naked globe, into which the whole surface sinks. The compression is not only throughout the whole extent of that circle, but also along the radii from the sun to the circumference. Not only does the gyration extend itself to the circle, but it also acts along the diameters or the radii. Consequently, it can be easily conceived that the particles that are near the sun are very greatly compressed, this compression terminating in a kind of globe according to the foregoing theory.

82. This globe of the fourth kind is so small, that the environing points are unable to impart to it a spiral motion.

Although the particle of the third kind is sufficiently expanded and ample, still the particle of the fifth kind or the small globe originating from the surface is relatively quite small. For example, in fig. 63, let *CDA* represent a particle of the third kind. Nevertheless, the particle of the fourth kind is still so small as to be equal only to the small globe *A*. The reason of this is that the surface *CDE* consists only of points of the first kind, which are so small that they impart scarcely any, or a very small breadth to the surface. Since, therefore, the surface is so small and attenuated, and since the whole surface becomes a small globe, they will give rise to a globe still smaller, so that we may almost consider it as *A* in *CDE*. For the more attenuated the surface, the less the size of the little globule to which it is able to give rise, since the whole surface passes into the spherical form.

Fig. 63.



If you choose to submit this to calculation you will see that from a very attenuated surface a very small globe may arise. But, in fact, if the surface were more extended or grosser it would be able proportionately to give rise to a larger sphere. Therefore, in considering the attenuated nature of the surface, and the smallness of the points of which the surface consists, it is not remarkable if this globe is small.

Since, therefore, this little globe is so small as to be hardly larger than the small globe which the points of the second kind produce by their fluxion, as at *B*; and since those points by their continual fluxion urge the surface *CDE* into a kind of spiral movement, therefore they cannot in the same way impel the small globe *A* into the same motion. The small globe is scarcely larger than the periphery or circumference which the points of the second kind describe; consequently, they are also able to impel it into a spiral gyration. A single point or two points of the second kind cannot impel the small globe *A* into the said gyration, but a continuous series of flowing points which continuously produce a surface ought to be able to do so. Therefore, on account of the smallness of the globe or particle of the fifth kind, it cannot be driven into that gyration by points of the second kind, which we elsewhere designate attenuated material, much less can it be kept in that state of gyration.

83. This small globe has the same weight as the particle of the third kind; and a volume consisting of particles of the fifth kind, or small globes, is very heavy.

One small globe of this kind equals in weight that of a single small globe of the third kind. From this it is evident that the whole surface of a particle of the third kind, where its weight resides, is concentrated in this small globe, whose weight, therefore, equals the weight of the surface. As to the attenuated matter, that is, points of the second kind, inside and outside the surface of the particle of the third kind, it can have no weight; for the point is in a state of continuous motion about a definite

centre, and cannot gravitate in any direction. But the superficies which consists of a continual series of points of the first kind will have a certain amount of weight, particularly if the whole surface is concentrated into a small globe. It is, therefore, evident that a particle of the fifth kind is equal in weight to the particle of the third kind.

It is clear from the preceding paragraph, that the particle of the third kind occupies considerable space, in comparison with the small globe or particle of the fifth kind; so that a thousand, and even more, such small globes may exist within the particle of the third kind. Since, therefore, both have the same weight, it follows that a volume consisting of a thousand particles of the fifth kind will have even still more weight than if the same volume consisted of particles of the third kind. If it were known how much space particles of the third kind occupied, and how much those of the fifth kind, it could easily be found from calculation how much weight a volume of particles of the fifth kind would have compared with a volume of particles of the third kind. It would be found that there is a great and almost enormous difference.

Since, therefore, a particle of the fifth kind is the most attenuated of all, and can in no way either undergo expansion or contraction, but is a compact body, it follows, therefrom, that a volume consisting of particles of this kind has very great weight, there being no matter in the solar world having such weight; that is, if these particles constitute one volume, or one body. But if the small globes are separated and acquire a new surface by expansion, of which we shall speak below, then much of the weight is lost.

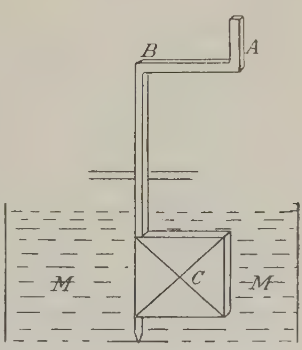
84. This great compression existed in the beginning of things, before the solar vortex was perfectly formed.

As to this compression, that is, the compression of the particles of the third kind into particles of the fourth kind, and the compression of those of the fourth kind into particles of the fifth kind,

of which we are here treating, this seems to have existed fully in the primordial state of things, or at the moment when the vortex itself was being formed. In the previous pages it has been shown, that the motion originated from a kind of ocean consisting of attenuated matter, where spiral movement impelled into motion all the matters adjacent to it. It has also been shown that the greatest velocity is near that ocean, or originant source, or sun. But since the surrounding matter had not yet been urged into any motion, but each particle in its own place, and at rest, produced its own gyration and its own fluxion, therefore, when that whole vortex was being urged into primary motion, greater resistance and opposition arose than when the motion was set up once for all. The case would be like that of impelling a boat of great weight on a certain course; although you pulled all the oars, and spread all the sails, you would not be able at once to get up full speed; but after a time, having been urged on its way by force of wind and sails and oars, the boat would then easily maintain its speed.

In order to make this point clearer, let, in fig. 64, *MM* be a vessel full of water. Let there be a rod with a handle *BA*; at the end let there be a flap *C*. Let the rod *B* turn about its axis by means of the handle *A*, causing the flap to revolve in the water. At first, there is a certain amount of resistance in the water, and opposition, as it were, so that a considerable amount of force is required to turn the flap *C*. But when you have turned the handle several times, then, the water having taken up the gyratory movement of the flap, the task of turning the rod becomes very easy.

Fig. 64.



The same would be the case if such a motion as this were set up in a vessel full of air. At first resistance would be felt; soon the air would be impelled to assume the same gyration as

the rod, and at length would easily follow the movement of the flap. So was it in the beginning of things, before the whole vortex could be impelled into a vortical motion. It is clear that there would be the greatest possible resistance, and, consequently, the particles would be subject to very great pressure; these particles of the fifth kind would, consequently, take their rise in the beginning.

But when the motion had extended to the extremity of the vortex, and the vortical particles had been driven into motion, then such pressure would no longer exist. For the particles would have already taken up the motion, one no longer exercising pressure upon another—except where there was still resistance, and the particles had not followed the motion—and there is only a slight but equal compression. It therefore follows that the particle of the fifth kind originated in the beginning of things, and can no longer be created. For it continues to be in the same abundance to-day as when it first came into existence, nor can any more take their rise in their own vortex.

85. The particles of the fifth kind cannot be in equilibrium with the particles of the third and fourth kind.

The particle of the fifth kind is so small that it does not equal the one-thousandth part of a particle of the third kind, nor is it endowed with motion and a homogenous sphere, in such a way that it can be moved at the same time as the particles of the third and fourth kind. They can occupy the interstices of the particles of the third and fourth kind, and in sufficient abundance, since there is ample space for them. But because all the particles of the third and fourth kind are surrounded with their own spheres, which are in continual motion, therefore, as soon as they come between those particles, they are immediately separated, because of the motion in such particles and in these spheres, nor can they in any way meet; so that when a particle of the fifth kind happens to flow between them, a conflict at once arises, and some amount of disturbance, on account of the great

dissimilarity, the particle being thrown aside to a considerable distance.

86. THE SUN IN THE BEGINNING OF THINGS WAS COVERED WITH A CRUST CONSISTING OF SUCH PARTICLES, AND WAS, CONSEQUENTLY, OBSCURED; THIS WAS THE ORIGIN OF SOLAR SPOTS.

Since the particles of this or the third kind could in no way preserve their equilibrium with the other particles, it is not wonderful that they constituted a definite volume, became conglomerated and occupied a place separated from the rest; and as no vortex had yet arisen, that is, as the motion of gyration had not yet penetrated to the extremity of the vortex, but was already beginning, as it were, therefore no separation of particles could exist, nor had any centripetal or centrifugal tendency yet sprung up. This characteristic came into existence with the vortex, when it was urged into regular motion, there being as yet no motion in the vortex, but only a perturbation; consequently, there could be no separation between light and heavy matters; whence this matter of the fifth kind was bound to remain in its own place; and as compression took place near the sun, therefore they occupied that place as their own, as it were, settled round it, and formed a crust. But on account of the enclosed mobile matter this crust or volume of particles of the fifth kind was bound to be perpetually urged into motion, so that that crust, by the help of the enclosed attenuated matter, was impelled to perpetually circumgyrate spirally. As to the spiral motion of this crust, we consider that the whole volume is impelled to circumgyrate spirally.

When, therefore, this crust circumgyrates spirally, it again urges the adjacent particles into motion, these again suffer compression, and the crust is augmented by a fresh accession. This augmentation continues a sufficient length of time for the whole vortex to be driven into motion. At length when the gyration has once begun, the compression is diminished, and the crust, with which the sun was obscured, underwent no further increase.

Since, therefore, such a crust of enormous magnitude surrounded the sun, it is not to be wondered at if, at that time, it was darkened, enveloped and obscured; and if one may be allowed to conjecture, one must suppose that this crust constituted the true chaos, which, when disrupted, initiated many things in the solar vortex of the planets. Thence new particles came into existence, forming the new matter which had partly settled down into their own vortices. We shall treat more fully in the following pages on this subject.

Here we see a fresh reason why new suns or new stars that have arisen in the heavens may be obscured, vanish from our sight, and be dissipated, as it were. For they may be darkened by a crust of this kind, which may also be augmented.

And since from this cause, matter which had constituted a vortex is absorbed, then the crust cannot but remain and the vortex disappear. It follows from this, that many stars may arise, but disappear from our sight.

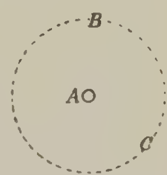
This, too, is the reason why spots still appear on the sun, and do so at irregular intervals, not returning at fixed times. This results from the motion near the sun being spiral. Consequently, unless we make such a calculation as agrees with this spiral motion, we can in no wise come to a knowledge of the coming and going of these spots.

87. In the meantime the sun is increased by attenuated matter, or that of the third kind, until the disrupted crust separates.

In the previous pages it has been shown how the solar ocean arises and grows from attenuated matter, that is, when the particles suffer compression into a smaller compass, and, in fact, into particles of the fifth kind; the spheres with which these particles had been previously surrounded then recede. And since the sphere consists of particles of the second kind, or of the same matter as that of the sun, therefore so great an amount of such matter remains, and recedes from its own particles. Consequently, it is not to be wondered at that such abundant

matter should insinuate itself into the centre or that originant source either through the peripheries or the poles of the sun. For if, in fig. 65, *BC* is a particle of the third kind, which holds matter of the second kind enclosed within, so that it has a surrounding sphere consisting of matter of the same kind, then, if this whole particle *BC* yields, or is compressed into the very small body at *A*, it follows that both the enclosed and the enveloping spheres will break up; consequently, this matter is bound to be either partly enclosed between particles of the fifth kind or to recede into the solar ocean; consequently, that originant source increases; and since the increase is considerable, it is not wonderful that the crust is broken up. The cause of the disruption of the crust was not only that distention, of which mention has already been made, but also the very rapid motion of the crust which increased more and more, in proportion to the amplitude of the sun, whence the entire crust, the chaos itself, and the heterogeneous mass was bound to burst asunder and become separated.

Fig. 65.



But there is another reason why the stars which come into existence in the universe, after a time become covered with a crust, and vanish from the sight. They have an insufficiency of matter; but all that matter which had constituted the vortex formed such a crust, whence the star was able indeed to be covered with a crust, yet the fountain or star concealed within could undergo no further enlargement by reason of the want of material, for the surrounding matter passes off into the vortices of the neighbouring stars.

88. In the crust previously mentioned, or in the volume of the particles of the fifth kind, there flows a considerable amount of attenuated matter or that of the particles of the second kind.

There are two reasons why there is an abundance of particles of the second kind or attenuated matter between the particles of

the fifth kind or the encrusting volume of the sun. The first is, that they are in the neighbourhood of the sun, where there is a definite aggregation, and where is the ocean of those particles or matter. Therefore, since that ocean continually acts upon the crust, they will be bound to insinuate themselves on all sides between the particles of the crust, and, consequently, conceal themselves among them; so that part of the crust will consist of particles of the fifth kind, and part of those of the second kind. They are the better able to insinuate themselves, since these are almost of the same magnitude. For the fluent points of the second kind can easily enter through the insterstices of the particles of the fifth kind; and when once they have entered, they can readily make a place for themselves by their fluxional movement. The fluent point itself is of very minute dimensions, but the circumference which the points describe by their movement is greater, consequently, they can easily enter the interstices of the particles of the fifth kind, and then by their fluxion make a place for themselves. It consequently follows that when on account of their proximity, they have come together in an ocean, as it were, they are not only able to enter among particles of almost the same magnitude, with their surface, but even to carry their motion there. Another reason is, that the particles of the third and fourth kinds possess a kind of sphere consisting of such points, which sphere is both enclosed within and circumfused outside the surface of the particle. Consequently, when particles of the third and fourth kinds are compressed into such a small globe, the sphere cannot immediately perish, nor can the enclosed and circumfused matter flow through; but if the way is not open to the sun, it remains enclosed, as it were, in the volume, from which it is unable to find a way of escape. This is, consequently, a second reason why the fluent points of the second kind are enclosed in an encrusted volume, and this is in agreement with our thesis.

For if the crust consisted merely of small globes of such a kind, then it would, as a consequence, be dissipated or broken up only with difficulty, especially if the crust were somewhat

dense; also if such matter were very heavy. Since, therefore, the crust has been disrupted, and the sun appears to us to be naked and unencumbered, it is an indication that that crust consisted of particles of the fifth kind mixed with fluent points of the second kind, or with volumes of such points.

89. Matter of the second kind acts upon these particles of the fifth kind, in the same way as it does upon particles of the first kind, and drives them into those surfaces, thus beginning a new particle, which we call a particle of the sixth kind.

It has been shown in the previous pages that a small globe of the fifth kind is still so small that fluent points of the second kind can by no means act upon its surface by any revolution; but since the small globes are so small, the points can only act upon them through points of the first kind, that is, they are able to move the small globes from place to place. Consequently, the action of the attenuated matter upon these small globes can take place only by means of the particles of the first kind; for they are able to operate not by any kind of revolution, but by a thrusting movement, although a greater amount of attenuated matter is required here than around the first points.

Since, therefore, points of the second kind are enclosed in the encrusted volume of the particles named, according to the proposition in the preceding paragraph, they, consequently, can act only upon the surrounding particles of the fifth kind, and slowly force these into definite motion. This, although small in the beginning, takes place more easily, because they immediately give rise to a definite spiral gyration, and, consequently, form two apertures in the particle at two poles, through which matter of the same kind again flows, and this gradually enlarges the particle until it attains the proper proportions.

Further, as to the origin of this particle it necessarily follows from the preceding propositions. For since the points of the second kind possess such a motion that they have a continuous spiral flowing movement, therefore, if they are enclosed, they

perpetually act upon the surrounding particles, until at length they draw them into a definite motion, and, when this is the case, set up in them a spiral motion like their own, and so again form a particle, which, in the same way, has a very great resemblance to a particle of the third kind.

There is now, therefore, a new particle, one whose surface consists of particles of the fifth kind, and in which are enclosed fluent points of the second kind; nor do these particles seem to differ at all from the particles of the third kind, with this exception, that they are larger, and that the surface consists of larger particles than the particles of the third kind; of this difference we shall treat in the following pages. This particle is, therefore, called a particle of the sixth kind.

90. Although the particles of the sixth kind have in the beginning different magnitudes, nevertheless they turn out to be equal when they form one volume.

These particles of the sixth kind cannot, at first, be of the same magnitude; for the attenuated matter flows now in greater abundance, now in less. Consequently, in the procreation of particles of this kind there is variety of magnitude; but when they form one volume, and acquire motion, then they are bound to be rendered equal both as to size and other qualities. The same matter flows between all, and attenuated matter is enclosed in all; the same motion takes place in all, and there is the same pressure; consequently, on account of this equality, all those particles of the sixth kind, which in the beginning had been unequal, are rendered entirely equal, because of the continuity of the motion and fluxion. For unless there were equality in magnitude, there could not be equality in motion, and contrariwise. Therefore, because of the uniformity of motion, which always exists in an element or volume of particles, there also arises a perfect equality of magnitude. For if one particle be greater than others, it at once suffers pressure from the smaller surrounding particles. If one particle be less than others, it is not

touched by the surrounding particles. Consequently the greater become less by compression, and the less increase in size, as a result of a greater amount of attenuated matter flowing up. These things can be geometrically proved, as all the rest can; but if we were to give ourselves up to proving each detail, this work would be increased enormously, and perhaps matters otherwise clear would become obscure.

91. Particles of the sixth kind are larger than those of the third kind, but they may be compressed until they attain a similar magnitude.

Particles of the sixth kind are bound to be larger, since their surfaces consist of greater and heavier particles. For the larger and heavier the superficial particles, the more extended can the surface become, especially if they have to be in equilibrium with lighter particles, although here equilibrium of weight cannot yet come into consideration; for the same matter is enclosed in both. But that they can be compressed into small dimensions, and how such compression proceeds, shall be shown later.

92. Their motion is also spiral, and they have two poles, through which the attenuated matter, or matter of the second kind flows in and out.

It is clear from what has been said above, that the attenuated matter, or that of the second kind, gives rise to this particle, that is, that that attenuated matter will continue to move between the particles of the fifth kind, until it at length draws over to its own motion the particles of the fifth kind, and thus generates the particle referred to; consequently this particle of the sixth kind holds attenuated matter enclosed equally as the particles of the third and fourth kinds. From this it results that it acts upon the surface of this particle in the same way as it acted upon particles of the third kind; the originant cause is the same, and, therefore, the motion must be the same. The difference consists solely in the superficial particles, which are larger in the particles of the sixth kind than in those of the third kind. If, therefore,

there is the same motion in both, the effect will be the same, that is, the movement of the surface of this particle must be spiral. This motion has been amply described in the theory of the particle of the third kind; it would, therefore, be superfluous to repeat it. It is sufficient to remark that there is the same kind of motion in the surface of the sixth kind as in the surface of the third kind, and since the motion is the same, it follows also that this particle has poles; that the polar cones are formed in the same way as in the particles of the third kind, that is, the surface is able to penetrate through the walls of the cones as far as the centre, and that the attenuated matter possesses also the said cones; but it has a different motion in the cones from what it has in the cavity of the particle. But more may be seen on these things in numbers 35, 37, 38, 39, 43, 44 and in those that follow.

93. The particle of the sixth kind has much in common with the particle of the third kind.

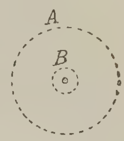
It would be tedious to explain all the qualities of this particle, since they have already been set forth in our theory of the particle of the third kind; for the motion is the same in both, the enclosed matter is the same, the motion in the surface is the same, the centripetal tendency is the same, and in both particles there is a kind of vortex. It would, therefore, be prolix to describe these qualities again. The reader may, therefore, be referred back to the theory of the particle of the third kind, and he will be able to apply to this particle, almost all that has been said about the former; this I here desire to indicate; both as to those things which have been stated regarding the movement of the surface and of the interior vortex, and those respecting its situation, and the forms and characters of the poles, etc.

94. In the interstices of these particles of the sixth kind flow particles of the fourth kind, together with attenuated matter.

In order that the truth of this position may be evident, let us consider again the qualities and nature of particles of the fourth

kind. Particles of the fourth kind are those which have been compressed, and conceal within at their centre a kind of small globe, which floats in the midst and revolves along the equator. The particle of the fourth kind may be so small as to be numbered among the minutest particles. Let A, fig. 66, be a particle of the third kind, then by compression this may be so diminished by the surface matter passing over into a kind of central globe, that it may become like B or still smaller. For since the small central globe or particle of the fifth kind is so small as hardly to be considered, therefore, also, the particle of the fourth kind may become smaller and smaller, until it becomes a small globe. Consequently, the particle of the fifth kind is unique in magnitude, and may be rightly regarded as among the minutest particles.

Fig. 66.



That this kind of particle is fluent in the interstices of particles of the sixth kind is plain from the fact that particles of the fifth kind, or small central globes, came into existence as a result of compression, and, indeed, near the sun; particles of the fourth kind also arose by means of compression. It consequently follows that part of the particles of the fourth kind were in that encrusted volume, and part in the vicinity of it; for where there was the greatest motion there would be the greatest amount of compression, and the greatest amount of compression was near the sun or around its crust as previously pointed out. So the crust, having been urged into a gyration, acts on the neighbouring particles, and in consequence exerts pressure upon them, until they become particles of the fourth kind; also the nearer they were to the crust, the smaller were they, in consequence of the greater pressure exerted there.

It follows from these things that between the particles of the sixth kind there ought certainly to be particles of the fourth kind; both because they were at the same time in the crust or encrusted volume, and because they were in its vicinity, so that there could not be other particles to fill the vacant interstices. Minuteness also assists the matter; for there could be 100 or 1000

such particles between three or four particles of the sixth kind. Whence it is clear that there are no other particles that could occupy that position. This might be proved by many other similar arguments regarding the nature of that element, concerning which we shall speak below.

That there is also attenuated matter between, also follows as a consequence, because the particle of the sixth kind encloses attenuated matter, or that of the second kind, according to the previous propositions; and it will be shown that this attenuated matter is able to flow in and out through the poles of that particle, in the same way as is the case in the particles of the third and fourth kinds. It has also been shown that the particle of the sixth kind arose from the motion of the said attenuated matter. Consequently, the attenuated matter is bound to be outside the particle either by rushing through its poles or arriving thither in another way. It is also clear that there is attenuated matter between these particles of the sixth kind; for the particles of the fourth kind which occupy the interstitial spaces have a vortex consisting of particles of the second kind, or attenuated matter. Since, therefore, that vortex continually accompanies the particle or its surface, it therefore necessarily follows that in the interstices of the particle of the sixth kind there is certainly attenuated matter, which fills all those places which the particles of the sixth and fourth kinds are unable to do.

95. The vortices consisting of attenuated matter maintain themselves with difficulty in the position around the particles of the fourth kind, and around those of the sixth kind.

It has been shown in the preceding pages that the vortices consisting of attenuated matter were formed around the particle of the third kind, and the particle of the fourth kind. These vortices seem to be specially capable of persistence, as long as equal particles are in one volume; so that if the volume consisted of no other particles but those of the fourth or third kinds, then the motion in all would be similar, and the vortices would be able

to be formed, and to persist when formed ; there are the same motion and the same arrangement in all. But, in fact, since in one volume there are particles of different kinds, as here, particles of the fourth and sixth kinds, therefore the vortices which are outside the particle are hardly able to persist ; there is a different motion, less or greater, in the particles of the sixth kind than in the interstitial particle, or that of the second kind. Also from the local motion 100 greater particles, or 1000 smaller or interstitial particles will certainly be moved ; consequently, since the particles of the fourth kind are not here in their natural position and have similar ones all around them, they can with difficulty be kept in their natural position. For as a consequence, through the slightest motion of the larger particle, or that of the sixth kind, they are disturbed, and become unequal in the motion of their own vortex. Consequently, there can be no vortex which resembles the one previously mentioned, either around the particles of the fourth kind, or around those of the sixth kind. Indeed, the attenuated matter flows round, and takes a vortical form from the least superficial or spiral motion of the particles. But since that motion is disturbed every moment, it cannot be said that, around the surface, there is any true vortex, but only a small and very slight one, which continually undergoes disturbance.

As to the interior vortex, that is, the attenuated matter enclosed in the particles of the fourth and sixth kinds, it indeed is permanent, although it undergoes various perturbations, of which we shall treat below.

96. THE PARTICLE OF THE SIXTH KIND HAS ITS OWN POLES AND POLAR CONES THROUGH WHICH THE ATTENUATED MATTER FLOWS IN AND OUT, AS IS THE CASE WITH THE PARTICLE OF THE THIRD KIND.

This particle of the sixth kind came into existence in the same way as the particle of the third kind ; that is, by fluxion of the attenuated matter. Consequently, when the said matter acts upon the surface of this particle, it is bound to urge its surface

into a spiral motion similar to, and homogeneous with the movement of the said attenuated matter; in the same way as was previously stated concerning the origin of the particle of the third kind. Since, therefore, the attenuated matter is within and gives rise to motion, that surface motion is bound to be spiral, and form poles, an equator and an ecliptic; for since the cause is the same, the same effect must follow. And when the poles are formed the attenuated matter will flow in and out through the polar cones in the same way as has been noted in reference to the particle of the third kind; and it will have the same motion in these cones as in the cones of the particles of the third kind.

97. The particles of the sixth kind preserve their own polar situation and are mutually in contact in the circles parallel to the ecliptic; but the interstitial particles, or those of the fourth kind, cannot do this if the larger particles or those of the sixth kind are moved.

The particles of the sixth kind preserve their own polar situation; from which it follows that the enclosed vortex or the enclosed attenuated matter drives the surface of that particle into a motion like its own, since its pole always has regard to the mundane pole. Consequently, they are bound to maintain the particle in that position, so that it may look to the mundane pole, or that the pole of the particle may correspond to the pole of the universe, just as is the case with the particle of the third kind, of which we have treated at sufficient length.

But as regards the interstitial particles or those of the fourth kind, these all look to the mundane pole, but because they flow between the larger particles, one of which can set moving one thousand interstitial particles, therefore, by the motion of one larger particle, one thousand, if not more, smaller ones are set in motion. Consequently, they are not able so exactly to preserve their position, because they revolve differently. But since that particle is impelled by the attenuated enclosed matter,

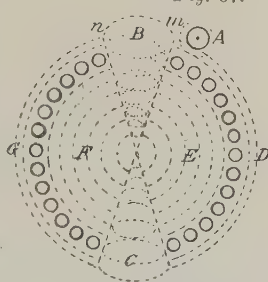
it is also immediately driven into that proper or natural position, in order, that is, that it may look to the pole, but after one or two preceding revolutions. In addition, the surrounding vortex is not so exact nor of such magnitude, as to be able continually to maintain those interstitial particles in their own polar situation, as in their natural position.

That the particles of the sixth kind are mutually in contact in the parallel circles of the ecliptic has been shown before in connection with the theory of the particle of the third kind; for the cause and reason are the same, consequently the effect is the same. Whence it would be superfluous to prove this point further. The paragraph itself may be consulted.

98. The interstitial particles, or those of the fourth kind, cannot easily be deflected to the poles of particles of the sixth kind.

Let *GFED*, fig. 67, be a particle of the sixth kind, *A* a particle of the fourth kind. The enclosed attenuated matter *FE* sets up the spiral gyration as far as the centre of that particle; also the feeble vortex *DG* is urged into the same spiral motion. But the attenuated matter in the poles *BC* is driven by another motion; as previously shown, and as the figure represents it. Consequently, there is one motion of the attenuated matter in the particle as *FE* and another in the polar cones *BC*. The same is the case with the particle *A* of the fourth kind.

Fig. 67.



Its vortex also has a spiral motion, as is the case with the greater particle of the sixth kind. Consequently, that particle *A* can easily flow into the vortex of the greater particle *DG*; for its motion is homogeneous with and similar to it; nevertheless, it is the fluxion of the same figure, whence they can very well flow and be conjoined, especially when the vortices move into the same spire. But when the smaller particle, or that of the fourth kind, goes to the pole of

the larger particle *B*, immediately another and dissimilar motion meets it, this being both in the vortex of the larger particle and in the vortex of the smaller. Consequently, since the motions are different, as soon as they meet there is opposition and a conflict, as it were, between the attenuated matter in each. Therefore, the smaller particle *A* cannot approach nearer to the pole of the larger particle than the surface in which *B* moves. Then, on account of the opposition, either it is cast aside, or merely flows around the polar cone measuring out the circle *mn*. Nor would it seem able to approach nearer, unless the smaller particle were deprived of its vortex, and at the same time all the attenuated matter, which is enclosed in the particle of the fourth kind were absorbed, which, in this case, is plainly converted into a small globe of the fifth kind, and so recedes to the surface of a particle of the sixth kind, the particle of the fourth kind thus vanishing. But this cannot exist unless it is impelled into the gyration of the polar cone *B* by some driving force.

99. Particles of the sixth kind cannot be conjoined round the poles.

It has been previously shown that particles of the third kind cannot be conjoined about the poles, and we have given the reason in our theory of that particle. And since the cause is the same, the motion is the same, and the attenuated matter enclosed in each is the same, therefore, the effect in regard to these particles is the same; it would therefore be superfluous to discuss this point further. The paragraph itself may be consulted.

100. The vortex of the earth consists especially of particles of this kind.

In regard to particles of the first and second kinds a definite vortex may consist of these, since particles are formed of those from which a vortex can arise; consequently, since they cannot be designated particles, but a kind of points and seeds of particles, therefore, no vortical quality can be ascribed to them;

but they are merely called particles, in order that all the kinds may be more accurately distinguished.

In regard to particles of the third and fourth kinds, we consider that the larger vortex of the sun consists of these, in which the vortices of the planets and the earth flow and move.

The particles of the fifth kind, cannot be called vortical or elementary particles; for they have no other quality than that which constitutes the surface of the new or sixth kind of particles; for they possess no motion except that which is in the surface of each particle.

In regard to the particles of the sixth kind, in the interstices of which the particles of the fourth kind are in motion, we consider these to be those of which the vortex of the earth consists, as also the vortices of the rest of the planets. But the truth on this point can by no means be made clear to the reader, unless it is illustrated and proved by arguments drawn from special experiments. Therefore, as soon as we have stated the origin of such vortices, we shall set forth the nature of these particles; this could not be done before the vortex existed, and set up its own motion in that vortex. For unless they are in a certain vortex and are moved therein, no elementary quality can exist among them. An elementary quality exists as soon as the particles are urged into a vortical gyration; but not before that motion is the origin of the vortex, and the movement is according to the motion, situation and pressure of the particles.

101. The vortex of our earth by a kind of revolution, and then by the circle of a definite ecliptic, gradually withdrew from the sun to its present distance.

The purpose of our principles is not indeed to show the origin of the larger bodies and of the planetary vortices, but only to describe the elementary particles and explain their properties. But because the procreation of these particles, and also their form and the properties which follow from it, cannot be made clear unless the history and origin of these vortices is dealt with according to our hypothesis, therefore, necessity requires that

the argument shall be continued and the hypothesis regarding the above subjoined; but because it does not directly tend to the end which we have prepared, therefore it is our intention only briefly to explain these matters.

When, then, the mass or encrusted volume around the sun was disrupted, so that it could no longer be continuous with it, but be in a state of separation and free; consequently, when it was of great size, and when that vast solar vortex in which the vortices of the planets and the earth flow, had been already formed, that is, when the particles or the entire vortical matter had been already urged into a regular motion, then, because this volume separated from that crust, by which the sun was surrounded, there could be no equilibrium among those particles near the sun; nor could there be equilibrium with the motion of those particles, which were also far lighter. Therefore, because in that greater vortex of the sun, there was a kind of centrifugal action, that is, the heavier bodies tended from the centre towards the peripheries, it is not remarkable, that this mass, consisting of alien particles of the sixth kind from the sun, and from the lighter element, and at the same time of particles driven by swifter motion, consequently by a definite centrifugal law—concerning which we have previously treated, and must also treat below—withdrew itself from the sun, and betook itself toward the periphery, or to a certain distance from the sun; and continued that course, or moved still further off, until it settled down, as it were, into a definite equilibrium among the heavier particles that were impelled by less motion—that is, by a general or vortical motion—thus a clearer conception is acquired.

It is evident from what has been previously said, that the sun, or the central ocean, consisting of attenuated matter, or of particles of the second kind, set up a kind of perpetual motion, and, at the same time, first impelled all the circumfluent matter into a kind of spiral gyration, but more remotely thence into a circle along the ecliptic, the reason for which has been stated above. Consequently, when the motion near the sun was extended thence toward the various peripheries, it follows, as

a consequence, that the motion of that matter was greatest about the sun, and less and less towards the peripheries, so that at a distance that vortical motion is diminished. This also is evident from the planets themselves; for the nearer they are to the sun, the more rapid is their journey round it; but the more distant they are, as in the case of Saturn, the slower is it, so that thirty of our earth-years are equal to only one of Saturn. Whence it is evident that the gyratory motion in the sun continually urges the surrounding matter into motion, and to a considerable distance therefrom, but that the motion decreases according to the distances.

When, therefore, such motion was begun and became perfectly regular, so that it might go on for ever, by God's will, then a vortex was formed. And in that vortex there are properties, of which we have in part spoken, and in part passed over. Nevertheless, one property or quality must here be stated, that is, that in such a vortex there must be a certain centrifugal tendency which causes heavier bodies to tend from the centre to the periphery.

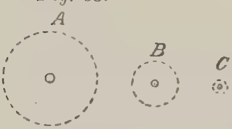
This centrifugal tendency is chiefly the reason why the motion differs according to the distances from the sun. For a body flowing in such a vortex is forced by a greater motion towards that side which looks toward the sun than toward the opposite side. In addition to this a body moving in a vortex tends to take a direct path, and thus along the tangents of its own gyration; but on account of the general flow of the vortex, it is restrained from doing this; it is, however, gradually carried toward the tangents and removed from the sun to the periphery. These things, however, pertain to another subject. It is sufficient for our purpose that in this solar vortex there is a some kind of centrifugal tendency.

Since, then, there is a definite centrifugal tendency in that large solar vortex, it follows also, as a consequence, that in that vortex particles from the sun are forced toward the surface, that is, the particles next the sun (that is, the motion has now become regular; in the beginning it was the contrary) are less

compressed than the particles which are removed to a distance therefrom. Therefore, because of the centrifugal tendency, the particles that suffer greater compression are more remote from the sun than those which are near it, consequently there is a difference in those particles in the large solar vortex which are near the sun. There are particles of the third kind that are more remote; there are particles of the fourth kind; and these are greater and less according to the pressure and their distance from their sun.

Since, then, particles of the fourth kind can be of very diverse magnitudes, as *A*, *B*, *C*, in fig. 68, therefore, those which are nearer the sun are like *A*, those at a distance like *B*, and the most distant like *C*; and finally, that vortex ends when the particles are so small as a result of compression that they escape, so as almost to lose their proper or spiral motion, and are almost changed into a kind of small globe or particle of the fifth kind.

Fig. 68.



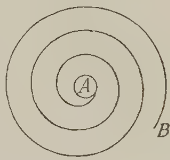
Since, therefore, the said particles are dissimilar in expansion and magnitude, and this difference arises from the differences in their distances, it thence follows that the volume of particles *A* is much lighter than the volume of particles *B*, and so throughout; and that the volume of particles *C* is much heavier than the volume of the particles *B* and *A*; whence the difference in weight is proportionate to the distances from the sun; and, consequently, if some heavy body is carried by centrifugal force from the sun to a certain periphery in the vortex, it may at length reach a certain periphery, where there is equilibrium. In that periphery the heavy body would have a stable position; for if it went farther, it would be carried outside its position of equilibrium, and back again to the periphery where the particles or volumes are in a state of equilibrium.

Since, therefore, the volume of encrusting particles consists not only of larger, but also of heavier particles, it, consequently, cannot possibly exist around the sun, because it would be carried by centrifugal force to some periphery more remote.

Hence, since the ordinary motion of the vortex is spiral, and has a kind of gyration along the ecliptic, this volume cannot be carried in a right line and perpendicularly therefrom, and thus come to a definite distance from the sun, being compelled to follow the common motion of the vortex, and for a long time to be carried round the sun, and to be gradually removed by that circular motion to a greater distance.

For example, if, in fig. 69, *A* be the sun, then the volume separated from the crust by a definite spiral circle must be carried thence, until at length it reaches that distance *B* where is the equilibrium of the volumes, so that the volume of such particles in the large vortex equals the weight of the volume in this vortex, or the weight of the vortex. This follows from the nature of the vortex, and from the centrifugal force which causes a difference in the different peripheries; consequently also at a certain periphery the volume is at rest and finds its equilibrium. This cannot be the case at the same moment, but gradually, and after several revolutions round the sun, or its own centre. For this reason it can be said, that many years were completed, before the vast volume or vortex of our earth, of which we have just now treated, reached its limiting boundary. Something also requires to be said about the vortices of the rest of the planets. But our purpose being to examine the variety of the particles surrounding our earth, and, consequently, to search out their natural and elementary qualities, therefore we leave the rest as being quite unknown and somewhat too recondite for us.

Fig. 69.



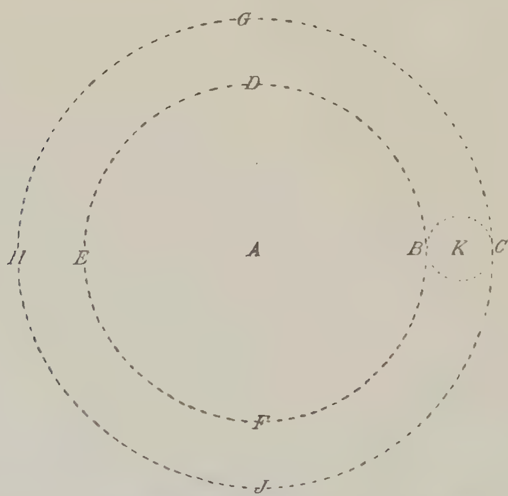
102. THIS VOLUME RECEDING GRADUALLY FROM THE SUN HAS A SPIRAL MOTION IN ITS FARTHEST PART, AND, CONSEQUENTLY, FORMS POLES.

In the preceding paragraph we have treated of the course of the motion of this volume from the sun and its ultimate gyratory movement, which gradually ceased, and so it acquired on its

path a double motion, one an orbital motion, and the other at right angles to the sun, whence a double motion results; for this reason it receded spirally from the sun according to the statement in the preceding paragraph. It is evident from these things that that volume moves round the sun, and, indeed, by a gyre along the ecliptic. In the previous pages it has been sufficiently shown that the entire motion of the vortex proceeds along the ecliptic, which the volume sent into that vortex also follows.

We have, therefore, treated of the annual motion of that volume, or of its flow around the sun. Here we must deal with the motion of the volume itself, which gives rise to the motion of the moon and also of our earth, along the equatorial circle,

Fig. 70.



and, consequently, imparts the nature of a vortex. For unless such a motion exists among the particles, the designation "volume" is correct; but directly this volume revolves, or even moves of its own accord, it must be designated a vortex.

As to the motion, then, if this vortex is in its extreme part or on the surface, it would seem to be spiral; but yet the spirals proceed along the circle of the ecliptic, so that all this motion takes place along the ecliptic of the large vortex.

As to the reason of this, consider fig. 70. Let A, the centre,

be the source of motion or the sun. Let K be the earth or that vortex in which the earth is enclosed; let the annual motion of the vortex be between the circles, for example at BC, DG, EH, FJ. But the motion of the large vortex is more rapid at B, since it is nearer to the sun, and slower at C, since it is further from the sun. Since, therefore, the motion is twofold, being different on one side from what it is on another, therefore the more rapid motion has the greater force and has a stronger action at B than at C. It, therefore, follows that there is no equilibrium of motion, it being unequal at every point; consequently, it is bound to take on a revolution, the motion being more rapid at B than at C. And since each motion acts according to its own force, on account of the inequality it acts more strongly at B than at C, whence it is bound to revolve in its own path around the sun, or annually, and set up a definite motion in itself. This can be proved experimentally. Let, in fig. 71, a sphere A revolve by aid of the arm BM. If the sphere A can also turn on its axis, then if this arm, at whose extremity the sphere is capable of revolving, be turned either in water or in air, then that sphere will revolve round its axis; and the more rapidly the arm is revolved the more rapid the motion. The reason of this is, that the resistance of the water or air is greater at a than at b, consequently, it tends to revolve in that direction; but if the resistance were greater at b than at a, the motion of revolution would tend in the other direction. It is the inequality of motion or resistance that causes the revolution. The same reason applies to the motion of the vortex of our earth.

Fig. 71.

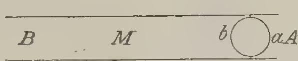
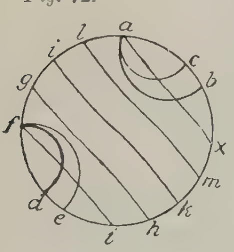


Fig. 72.

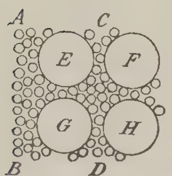


This revolution can be no other than that which is seen in the flow of the large vortex, that is, along the ecliptic. For the circle of fluent matter in the large vortex is the ecliptic. Consequently, if it acts in a similar manner at x, fig. 72, as $mkhi$ towards $alig$, the whole revolution is bound

to be along the ecliptic; but because that surrounding matter acts not only in *mk*, but also in the smaller circles *xh* —and there is a greater diversity of motion around *mkig*, than round *xh*; therefore, there is a spiral action, so that the pole of the ecliptic *cd* changes its position and its own movement round the mundane pole. This is the reason why the lunar ecliptic changes its nodes with the earth's ecliptic or with the equator.

That the fluent matter in the large vortex has the power to cause this whole vortex to revolve is evident from this, that the material of the large vortex consists of small particles of the fourth kind, as *AB* in fig. 73. The matter of the earth's vortex consists in part of particles of the sixth kind, *E*, *F*, *G*, *H*, and in part of those of the fourth kind, which float about as enclosed particles. Consequently, the fluent matter *CD* cannot be otherwise considered than as contiguous to the matter of the large vortex, and, consequently, more easily communicates its own motion. For, since all the particles act at the same time by their own motion, and, indeed, 100 or 1000 particles of the fourth kind upon one particle of the sixth kind, therefore, they must absolutely obey this motion; and because the torrent or stream acts more vehemently on one part than on another, it, consequently, sets up a revolution in the way previously shown.

Fig. 73.



In addition to this there is no motion of revolution near the poles of the equator, and the poles of the ecliptic; for there is not much difference between one side and the other, consequently, there is not much difference between the motions; but they are almost coincident here. Hence no motion of revolution can be set up there; but the force is very great round the larger circle, or the ecliptic, whence the poles are formed.

103. THE MOTION ROUND THE CENTRE, OR THE MOTION OF EACH CENTRAL GLOBE TAKES PLACE ALONG THE EQUATOR.

We have explained the reason of this in the previous pages when treating of the particle of the fourth kind, and the small

globe enclosed in it. For the matter flows spirally through the polar cones; and this spiral action terminates near the centre in a circle perpendicular to the polar cone, whence the revolution at that place is bound to be near the equator.

We also gave another reason, namely, that the spiral path in the vortex naturally and geometrically ends in a regular motion, that is, in a motion along the equator. It consequently follows, that there is another pole of the ecliptic, if that motion be considered which is near the surface, and another, if that motion be considered which is nearer the centre. For the nearer the motion of the vortex approaches the centre, the more does the pole of the ecliptic approach the mundane pole; and, at length near the centre, or near the central globe, the pole of the ecliptic coincides with the mundane pole. Concerning these things, see what has previously been said about the particle of the fourth kind, and about its central globe.

104. MOTION IN THE BEGINNING OF CREATION WAS MORE RAPID THAN AFTERWARDS, AND, CONSEQUENTLY, THE YEARS AND DAYS PASSED MORE QUICKLY; BUT THE MOTION OF THE TERRESTRIAL VORTEX WAS ALREADY DEFINITE AND FIXED, SO THAT IT COULD ONLY BE CHANGED BY THE WILL OF GOD.

That motion in the beginning of creation was altogether more rapid is clear from this, that at that time the extent of the volume stretching from the sun to the periphery, which now exists, gradually decreased. And, consequently, it was nearer to the sun, but by gyrations and numerous revolutions it at length reached a certain circle in the vortex where it came into a position of stability by its own weight. When, therefore, this volume had measured out that space, or described these revolutions, and was nearer the sun, its annual revolution round the sun must certainly have taken place in less time; for the circle was less and the motion more rapid: consequently in the beginning the solar year was completed in a few days, afterwards it took weeks, and, at length, months.

But as to the diurnal revolution itself of the earth, that also seems to have been more rapid; for the motion of the large vortex near the sun was more rapid than at a distance therefrom, according to what has been proved in the preceding pages. Consequently also the revolution of the volume, or of this vortex, must have been more rapid. When the motion is stronger, then also a stronger effect follows; therefore that motion of revolution seems to have been very rapid. And since, in the extreme limit of the vortex, it was very rapid, it necessarily follows that the gyrations as far as the central globe were very rapid, and similar to the motion thereof. According to our theory, therefore, night and day could be completed within the time that corresponds to our hours, that is, three or four revolutions would have been completed within twenty-four hours of our time, and, nevertheless, three hundred and sixty, or three hundred and sixty-five, days might have been passed through within the space of a year.

How many years elapsed before the vortex of our earth attained the orbit in which it now moves cannot indeed be exactly calculated, nevertheless I maintain that it would not be so difficult for mathematics to deal with such matters; certainly a great length of time must necessarily have elapsed.

But when it had now reached the circle, in which the vortex with its surrounding matter maintains its equilibrium, there would seem to have been no further effort to reach a more distant periphery or an orbit more distant from the sun; but there it lay as if in its own bosom, and was quietly carried round by the stream of the primary vortex, and with this motion it completes its years; and by the motion of its own vortex its revolutions, or its days and nights, are described along the equator. Nor would it appear that the earth's vortex could approach nearer, or recede farther from the sun, but that it would continue to move in its own orbit for ever, unless, God willing, the motion of the large vortex underwent a change through some other large vortex coming into existence in its

vicinity, or its circles suffering perturbation from the rushing of some comet into this large vortex.

That in the beginning of creation the years were not so long as they are to-day, or that the yearly course of the earth described a smaller circle or gyration around the sun, also that its motion was more rapid, so that the year, although it had as many days, nevertheless was only $\frac{1}{10}$, $\frac{1}{9}$, $\frac{1}{8}$, $\frac{1}{7}$, $\frac{1}{6}$, $\frac{1}{5}$, $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, $\frac{3}{4}$ of the length of the year at the present time; and again that the diurnal revolutions of our earth were performed within much less time than now—all this would appear not only to be consistent with our theory, but also with the history of ancient times.

The Sacred Scripture makes mention of paradise and all the delights of a garden; this garden, however, does not appear to have flourished for long. It would not seem unreasonable to think of a perpetual garden which clothed the whole earth, or to suppose that the whole surface of the earth was covered with delightful little gardens, when the yearly journeys of the earth were accomplished in a sufficiently short space of time. Thus the times of the year would follow one another with a brief interval, autumn immediately followed summer; winter the autumn, and spring winter. Hence the sun's heat in summer was tempered and reduced immediately by autumn and winter. The cold of winter could not last long, for it was at once followed by the temperate periods of spring and summer. In addition to this, the diurnal revolutions also rendered the temperature equable. The cold of night was nullified by the heat of the day, or mid-day, and contrariwise, the heat could not attain any high temperature; for as soon as the cold began to increase through the absence of the sun, the morning, and the rising of the sun followed; nor was sufficient time left for the increase of the cold at night or for the mid-day's heat; for changes took place swiftly and alternately, and within the briefest periods. Consequently, it follows from our theory that there must have been certain parts at that time that resembled a garden.

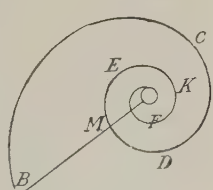
In addition to this, there succeeded the golden age; this

was followed by the silver age, and at length by the ages of iron and clay, as the poets sing, a sign that former ages bore some resemblance to a pastime and the noblest metal, and that nature herself, most pleasant and delightful, wore a very joyous countenance; and that there was nothing anywhere throughout the whole world that did not flourish and enjoy its youthful prime. But as time passed those joys and sports of youthful nature put on a mournful aspect, that is, our earth gradually withdrew to a greater distance from the sun, and the annual and daily revolutions, consequently, became more protracted. As a result of this also the intervals of winter and summer, of day and night, increased; from which it follows, that in winter the cold became keener, and in summer the heat more intense than formerly; and, consequently, as nature increased in age, and grew old as it were, she became less pliable, there being, as in the case of men, less joyousness.

From the Sacred Scripture it is clear that in the beginning animals were created, and that fishes and creeping things came into existence; but all these things came forth from the earth itself and the ground. For the Scripture testifies that the Almighty commanded that the earth should bring forth animals, and the waters fish of all kinds, and that man himself should be formed from the soil. Also at that time the seeds of trees and flowers were scattered over the surface of the earth, and many other things which indicate that the state of nature on our planet was quite different from what it is to-day. That is, nothing on the earth became torpid from long continued heat or cold; but there was, as it were, a perpetual spring, and a medium temperature between heat and cold. For unless the climatic conditions as to temperature had differed greatly from those of to-day, I hardly see how, in obedience to Divine command, animals and fish of all kinds could have been produced, with the earth and the sun as the means. When Omnipotent God commands He supplies the means, and imparts strength to the earth and a procreative virtue, which it is likely to have had since it was at a middle distance from the sun.

The same thing can be proved from the long life of the patriarchs. This may be partly attributed to the simplicity of their food, to their unsophisticated habits of life, and the consequent peaceful state of their minds; and partly to the extremely short length of the years. For in this way the patriarchs could pass a hundred years or what is the same, they saw the return of a hundred winters or summers, where we count only ten. Yet the period of a hundred years with them equalled only ten of our years, as follows from what has been previously stated. But the years returning so quickly seemed shorter, so that afterwards the posterity of Noah scarcely reached a hundred or a hundred and twenty years. This follows from the fact that the vortex of the earth departed from the sun by a definite spiral gyration. And, in fact, in the beginning it described only small gyrations, nor did it recede a great distance from the sun. But when it had proceeded a distance therefrom, and the effort to reach the periphery was increased as the square of the times, then the earth was able to advance within a few years, or at least, within fifty or eighty from *M* to *C*, fig. 74, and arrive at the orbit in which it now moves to-day. Consequently, the ages of men, in so short a space of time, appeared to diminish, say from seven hundred or nine hundred to one hundred or one hundred and twenty years. The reason of this we have stated in the previous pages.

Fig. 74.



Much other additional testimony could be adduced which would seem to confirm the theory of this paragraph, but since what we have brought forward already is sufficient, it will be enough to quote Ovid on primeval ages.

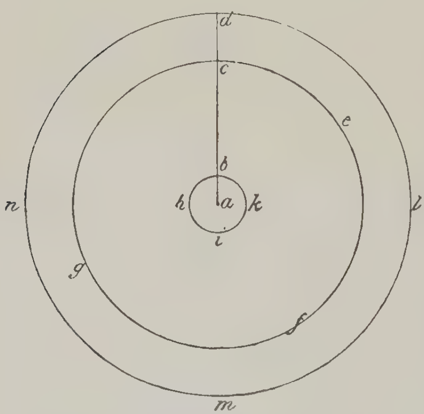
> The golden age was first; when man, yet new,
> No rule but uncorrupted reason knew:
>
> . . . .
>
> The flowers unsown, in fields and meadows reigned:
> And western winds immortal spring maintained.
> In following years the bearded corn ensued,
> From earth unasked, nor was the earth renewed.

From veins of vallies, milk and nectar broke ;
And honey sweating through the pores of oak.
But when good Saturn, banished from above,
Was driven to Hell, the world was under Jove.
Succeeding times a silver age beheld,
Excelling brass, but more excelled by gold.
Then summer, autumn, winter did appear :
And spring was but a season of the year.[1]

105. THE MOTION IS MORE RAPID THE FURTHER IT IS REMOVED FROM THE CENTRE OR FROM THE EARTH ; BUT, NEVERTHELESS, ONE REVOLUTION CAN BE DESCRIBED ABOUT THE SURFACE OF THE VORTEX, WHILE SEVERAL MAY BE DESCRIBED IN THE SAME TIME ABOUT THE CENTRE.

The gyration of the vortex must not be understood as being so swift as to revolve more often, or as many times in a day as the earth itself along the equator. There is no doubt that the movement of the vortex about its surface is more rapid than nearer to the centre. For the gyration commences in the surface, as we have shown before. For it proceeds from that source toward the centre; therefore it is diminished, or the velocity becomes slower the more distant it is from its source, or from the surface. Consequently, the velocity of our earth is much less than the velocity about the surface. But the gyres or circles, although the motion is swifter, can nevertheless be described in the same time; but the larger the circle the more time will be consumed in describing it. For example, in fig. 75, let

Fig. 75.



[1] Ovid, *Metamorphoses*, bk. i. 89-118, translated by John Dryden.

ndlm be the circle, which the surface of the vortex describes with the given velocity. The circle *cefg* is smaller, but its velocity is greater; *bkih*, or the earth, is a still smaller circle, which is described with less velocity; consequently, the smallest circle *bkih* is described ten times while the circle *cefg* is being described once or twice, and yet the velocity in the circle *cefg* is greater. The circle is larger, consequently, although the velocity in it is greater than in the small one, *bkih*, still the circumference is described only once with greater velocity, although the velocity in the smaller is twenty or thirty times less. For example, let the diameter of the smaller circle *ab* be 1; the diameter of the larger circle *ac* 5; then, if the velocities were equal, the smaller circle *bkih* would revolve five times while the larger one *cefg* would describe only one revolution. But if the smaller circle revolved three times, while the larger one *cefg* revolved once only, then the velocity of the revolution of the greater circle would be greater, although it revolved once only; and the velocity of the smaller circle would be less, although it performed a revolution in the same time.

It is for the same reason that the moon in the earth's vortex revolves in its orbit in twenty-eight days, although the earth makes one revolution in twenty-four hours. For the diameter of the circle which the moon describes is so large that the motion of the moon or the motion of that circle is more rapid than the motion of the earth in its revolution around its axis. The same is the case with the rest of the circles in the same vortex; the farther they are removed from the terrestrial globe, the more rapid is their movement; and the reverse is also the case. But that it takes several days to describe the circles, when the earth performs its revolution in one day, results from the amplitude, or the greater diameter of the circles; and the difference of motion depends on the difference in the size of the circles.

106. With a given motion from the periphery to the centre, a kind of vortex arises, the flux of whose particles tends to the centre, and consequently a centripetal tendency arises in our vortex.

It has been stated that in the vast solar vortex there is a centrifugal tendency, that is from the sun to the circumference; for the motion near the sun is very great; but less in the circumference; consequently, the heavier parts from their greater motion tend to the place of slower motion. The reason for this has been stated in the previous pages, and requires to be further dealt with.

1. Since the motion undergoes a diminution from the centre toward the circumference, therefore any body from that part where there is the greater motion, is impelled with greater force than if it came from another direction, where the motion is less; consequently, the body, impelled by greater force, is driven into the circle where the motion is less. This agrees with geometry and experiment.

2. Another reason is, that a body in such a vortex is compelled to follow its general movement, and to describe revolutions or circumferences in accordance with it; consequently, when this body is carried by the general flow of the vortex it is bound to have a tendency to rush off at a tangent, but every instant, when it strives to do this, it is driven from a part where the motion is greater toward the centre or the surface, and, consequently, in that general motion of the vortex it descends or ascends in agreement with the centrifugal or centripetal tendency.

3. Since the particles in such a vortex are mutually incumbent upon one another, so that a higher particle rests on a lower, therefore, a difference in the particles arises in each circle. A heavy volume cannot subsist in a light volume unless it is impelled, by causes previously mentioned, either to the centre or from the centre to the circumference; consequently, every instant the state of the particles is changed; and this is different in

every circle, whence at length it passes from the lighter to the heavier element or volume, until finally it falls into that element or circle whose volume equals the weight of the volume of the body. But more will be said on these points in the following pages.

107. The particles contained in this vortex, in consequence of this motion and centripetal tendency put on various elementary properties.

The volume of such particles could, of themselves, have no properties unless it were continually impelled under the influence of some kind of motion and gyration. Therefore, the volume of our vortex, before it was impelled to take a spiral motion, could have no elementary properties, before it was driven into gyration ; then it first put on a nature which we call elementary. For if a volume without such gyration and motion be thought of, then, nothing can enter into consideration but the central motion of some particle. Also, as no particle rests on another, and there is no regular arrangement among the particles, the distance between the particles must be unequal; and clearly nothing can take place there that can come within the category of elementary particles. But immediately the matter of this volume is impelled to gyrate, and the resulting gyrations begin in the surface, and continue toward the centre, then the elementary quality among them is made manifest; then the volumes have to be considered according to their amplitude and compression. There exists, too, a kind of centripetal tendency of the heavier parts : and innumerable other things take place which must be separately dealt with. Therefore we must conclude, that this circular motion is the principal cause of phenomena and of elementary properties, because these had no previous existence.

But to determine the moment and time when this vortical nature came into existence and first gave rise to elementary properties, we must suppose that they did not exist when this

volume constituted one part of the crust around the sun, but that as soon as this volume broke away from the crust, was separated from it and driven from the centre, it then immediately entered on its path and attained to a certain distance from the sun. Then from the motion of the large vortex, according to what has been previously said, the volume was immediately urged into a gyration, and the earth into the motion causing night and day and also the yearly motion. And when this motion reached the earth, so that it also was caused to revolve, there the said elementary qualities seem to have first begun, that is, elementary nature came into existence together with day and night before the changes of day and night supervened. Nor does any elementary nature, such as we know it to-day, seem to have come into existence; consequently it seems to have begun at the same time as the motion of the earth.

108. The particles of the sixth kind rested upon one another in the vortex, and gave rise to a gradually increasing pressure toward the centre.

It has been previously stated that this vortex of the earth consisted of particles of the sixth kind, and of interstitial particles of the fourth kind.

Now, with regard to particles of the sixth kind, these particles are peculiar to this vortex, or its common material. The interstitial particles of the fourth kind are also in common with the particles of the large vortex, in that circle. These particles of the sixth kind move vortically from the periphery to the centre, and, since a definite centripetal tendency arises from this motion, it therefore follows that one such particle rests on another, from the surface to the centre, and thus is the cause of the incumbent pressure which gradually increases from the surface toward the centre.

We shall treat of this pressure below when we deal with the birth of particles of the seventh and eighth kinds.

109. The radii, which are said to be perpendicular in this vortex, do not proceed in a straight line, but run in a curve.

Let us imagine a stone or other heavy body gliding from the extreme surface of this vortex to the earth as far as its centre, I say that, then not a right line, but a curve would be described, or that a perpendicular line is not straight, but curved. The said stone undoubtedly follows in its fall the common motion of the vortex, and so when a space of time intervenes it is carried somewhat along the horizon; and since the earth moves also at the same moment according to the same gyration, therefore, it always tends to the same place, and thus the line is said to be perpendicular. But because it is at the same time carried in a parallel horizontal circle, it departs from the true line, and therefore it glides down with a twofold motion, one along a horizontal line, and another along a line leading to the centre; consequently a curve is bound to be described.

If one also considers that a circle far from the centre has not the same motion as one near to it, then, if a stone falls from the surface of the vortex to the centre, the line will appear to be curved; and, therefore, a line which is said to be perpendicular, is actually not a straight line but a curve; in comparison, however, with the general motion, which otherwise must be regarded as rest, it may be called a line.

110. The gyration of the terrestrial vortex may be more truly called rest than motion.

The elementary particles themselves which are the cause of the centripetal tendency of all things are carried round in a large circle; and the surface of the earth and the inhabitants who live on it are not moved independently by that surface, but together with it; consequently the surface of the earth cannot be said to move, but, rather, to follow the general motion, and to be borne, as it were, at rest in the bosom of something; like any kind of body in the air or

in a vortex; which shows that this general motion cannot be said to be motion, but may be spoken of as quiescence. It may be compared to an infant in its mother's womb, which does not move, but follows, as it were, the motion of its mother. So also a sailor on board a ship which is driven along by its sails, may be at rest on the vessel, although, in relation to the sea and the land, he is moving. Similarly with a drop or volume of water in some body or vessel that is in a state of motion. For when a body follows the volume of an element, it is in a state of rest in the element; but the element itself is the subject of motion. For the same reason an element is in a state of motion in its own vortex, and the earth similarly. But whatever is the subject of the same, motion may be said to be at rest in the body or element, but not to be in motion. The motion is relative to the neighbouring parts, in reference to which the motion may be said to be localised. But when the neighbouring parts become the subject of motion, then everything is in a state of motion, but whatever is enclosed in the body that is moved, is at rest. Therefore the vortex in respect to the bodies which are outside the vortex is the subject of motion; as for example the sun, the neighbouring stars, etc., in relation to the matter which flows extraneous to them. But whatever in that vortex obeys the said motion cannot be said to be moved in relation to any matter whatever contained in the vortex. The same applies to this body, if anything is enclosed in it, and so generally.

111. Matter consisting of particles of the sixth and fourth kind flows in through the poles, by which the lack of that matter around the earth is supplied.

There is another motion of the particles in the polar cones, as was previously shown. But as to the nature of this matter, it is evident that it is the same as that which is in the surface, or the outermost part of this vortex; consequently, the same matter flows in through the poles, as elsewhere flows in the

outermost part of the vortex, since that matter is less compressed; therefore it enters continuously in a gyratory manner. And if there is any lack of that matter around the earth, it is supplied by the new matter which flows in through the poles. If the vortex suffers compression from other vortices or from other causes, then more and more of that matter flows in through the poles; and when it reaches the central circle, it undergoes compression, and, consequently, the volume or extent of the vortex may suffer diminution. Whether anything enters through the poles which finds its way across from the vortices of other planets, is not the point under consideration, nor can it be definitely determined.

112. In the beginning of creation the pressure around the equator was far greater than at the present day, and consequently water from the earth's equator was carried to the poles, where it stood at a greater height at that period.

It appears from considerable evidence that the ocean in primeval times was deeper than at present. Witness the many mountain peaks which seem to have been entirely submerged in which vestiges of some ocean can be discerned. [Fossil] fish in mountain caverns and also on their very summits testify to the fact. Shells bear witness to the same fact, and also various kinds of *testudo* which lie at great heights on the very tops of mountains in great abundance. Thick strata of *testudo* can be seen near Mount Bohusia lying at a height of more than a thousand yards from the surface of the ocean, as the dwellers there have burnt lime from them for a hundred years, and there are sufficient to last a hundred years more. The whole of our earth, which has an uneven surface, is here and there strewn with enormous rocks, here elevated into hills, there again marked by rocky peaks, here by depressions; and there are a thousand other indications all tending to the same end, proving that our earth was once under the sea, or that the depth of the ocean was formerly greater than it is to-day.

The cause of this can be seen below, where the origin of salts and metals is treated of. For when water passes into salt and rocky matter its height is quite diminished. But our purpose in this place is to prove that the height of the ocean was greater toward the poles in former times than to-day. The reason of this is clear. When the vortex of our earth receded from the sun to the orbit in which it now revolves, on which journey it probably spent a thousand years, then, as a result of a greater and more intense motion of the solar vortex, its motion gradually became less and less. The more rapid motion of the large vortex was near the sun; and, consequently, the action upon the equator of the earth's vortex was greater. For the greater the motion, the greater the action; and, consequently, the greater was the pressure upon the said vortex of the earth. For before it chose to follow the general motion of the large vortex in that intenser motion there must have been resistance; and if the resistance and motion were greater, it follows therefore that the pressure was greater. The greatest pressure was upon the vortex of the earth near the equator or the ecliptic, where the circle is the largest. Therefore, on account of that pressure upon the larger circle, there was also pressure upon the ocean or the water with which the earth was surrounded; and, consequently, the ocean being subject to pressure more about the ecliptic or the equator than about the poles, the water toward the poles then stood at a greater height than to-day. But at the present time, since the motion or pressure is not so great, the water has gradually receded from the poles and seems to have betaken itself towards the equator.

113. Particles of the fourth kind, which in the vortex of the earth flow between the particles of the sixth kind, also suffer compression in the vortex through the centripetal tendency, as also particles of the sixth kind.

In the vortex of the earth, particles of two kinds suffer compression; for each kind of particle takes on the nature of a

vortex by means of motion. Particles of the fourth kind are indeed so separated from those of the fourth kind, which are outside the tellurian vortex, that they flow between particles of the sixth kind and there pursue their motion. Hence when particles of the fourth kind are moved by means of gyrations, which are continued from the surface towards the centre, then a kind of elementary nature arises among them; also between particles of the sixth kind. As a consequence, from the surface as far as to the centre they are gradually compressed according to the ratio of the distance, just as the particles of the sixth kind; but yet the pressure of these particles is not derived from particles of the fourth kind nor contrariwise, but each kind derives its elementary quality from the vortical motion of which we have previously spoken.

114. THE UNDULATION PROCEEDS VERY RAPIDLY IN SURFACES OF THE THIRD, FOURTH, AND SIXTH KIND OF PARTICLES, BUT WITH A DIFFERENCE OF RAPIDITY IN EACH CLASS OF THESE PARTICLES.

The theory of undulation in particles is of great moment, for it explains the unknown quality both of light and other phenomena; consequently, it is of great consequence to investigate its nature more deeply.

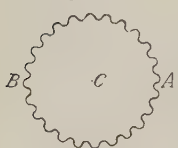
As to undulation in particles, it serves to show what is the nature of undulation in any particle; since the particles of the third, fourth, and sixth kind are very much alike, but differ only in magnitude, therefore I desire to explain the nature of undulation in all these cases.

By undulation is meant motion on the surface of a particle by which the surface is simply moved or undulates without the particle itself being moved as a whole. For if the particle itself were carried from place to place, there would be no undulation; nor if the centre of the particle were moved reciprocally with the surface, but only the surface undulated, the centre of the particle being at rest. Just as if you were to strike a distended bladder, its surface would be reciprocally moved, the centre

of the bladder remaining quiescent. I therefore designate undulation, motion in a struck surface only.

As to these particles of the third, fourth, and sixth kinds they are well adapted to receive undulation in the surface. For a particle consists only of a very thin and mobile surface, and that surface has attenuated material enclosed within it, which like a vortex tends to the centre and distends the surface of the particle with perfect uniformity. Therefore particles of the third, fourth, and sixth kind are highly perfect mechanisms for the reception of undulatory motion, by which nature affords such a variety of phenomena to our eyes and senses. In a word, the said particles are, as it were, fashioned and born for taking up that extremely rapid motion, and extending it throughout their entire surface. Let *BCA* be the surface of a particle of the third, fourth, or sixth kind. If this surface be struck at a very small point, so that one part undulates, then that undulation will immediately run round the particle and, indeed, throughout the whole surface; nor will it cease before it has returned to its former state. This minute point on the surface traverses the whole and every part of it. Consequently, if a blow be struck at one point, that percussion or undulation will extend to all points, or to the whole surface. For it extends in an instant to the entire surface and produces everywhere the same effect as if that surface were undulating although there is only one point.

Fig. 76.



Nothing prevents the point running throughout the whole surface under the influence of this undulation. The attenuated matter which is enclosed can offer no impediment; for it very easily yields, and gradually gives way by its own expansion, and diminishes the undulation that has begun. Nor does the surrounding matter offer an impediment, as is also evident from that attenuated matter, which does not react and fight against the given motion—consequently, any point that has taken up the undulation can run in a moment throughout the whole surface. Whether one minute part of the surface can

communicate its own vibration to another minute part or from a neighbouring point in the same surface I hardly know.

Now no definite reason can be given for the undulation, unless it be found in the element itself, which possesses elementary properties; but, in fact, in the surface of such a particle no elementary property exists, so that one particle rests on another, and communicates its motion to a neighbouring one, and then the motion in the neighbourhood is dissipated. But we must rather consider that the particle which receives the vibration, maintains it throughout its entire revolution; the same is the case if several points of the surface take up the vibration at the same time; but of this we must treat below.

As the mode of vibration has been explained, and its nature in the surface of the particles, that is, that the points in the surface run over the surface like a wave, the particle being at the centre at rest, we must now explain the difference existing between the vibration in particles of the third, fourth, and sixth kinds.

In a particle of the third kind the vibration is very rapid; for there is nothing to impede it. The surface consists of points of extreme lightness; the interior parts consist of attenuated matter, which matter facilitates rather than impedes undulatory motion; the exterior parts consist of attenuated matter; and there is nothing to offer any obstruction but the very rapidly vibrating point which runs over the entire surface and indicates that almost the whole of it is in a state of undulation.

In particles of the fourth kind the vibration is still more rapid, and within the same instant is able to run throughout the entire surface; for the particle of the fourth kind is less than the particle of the third kind, and the motion of the surface more rapid in regard to the succession of the revolutions. And the matter forming the surface in particles of the fourth kind is the same as that in particles of the third kind. Hence the vibration runs more quickly over the surface of particles of the fourth kind than over the surface of particles of the third kind. And since particles of the fourth kind are very different in

magnitude from the former, therefore the less the particle of this kind or the more it is compressed—it is not, however, so compressed as all to pass into a small globe—the more rapid the vibratory motion; as follows from what has been previously stated.

But the vibration in particles of the sixth kind is slower; for the points on the surface are larger, or the matter forming the surface is heavier, and, therefore, not so adapted to vibratory motion, as the extremely light points in the particles of the third and fourth kinds. But since the matter on the surface of particles of the sixth kind is not too heavy to prevent its being well adapted for vibration—for there is the same attenuated matter within and the same yielding quality as in the foregoing—therefore it is also adapted for vibration. The only difference apparently is, that the vibration in the particles of the third and fourth kinds is slower. But although it is very rapid in respect to our senses, the surface is of greater extent, consequently, the path traversed by the vibrating point or particle of the fifth kind is greater. In addition to this it is somewhat heavier, consequently, the vibration in the particles of the fourth kind is exceedingly rapid; also the less the particle of the fourth kind the more rapid the vibration. Then follows the particle of the third kind which has a less rapid motion; and last in this class comes the particle of the sixth kind.[1]

115. Vibration can be imparted to several points in the surface at the same time, these points either cohering or being mutually separated, and yet the vibration so imparted may proceed regularly.

The vibration is least if it moves only one particle or one point in the surface; but it rarely happens that a vibration is so small. Several points or several surface particles may

[1] In the margin of the MSS. these words occur: "Note below, that the vibration in these particles takes place differently, that is, by the reciprocal expansion and compression of a particle."

be set in motion at the same time. For example, if in fig. 77, the surface be struck at A by another particle, then not only one, but several points are struck and set in motion. Also the greater repercussion and the greater vibration, so that the vibratory motion can affect much of the surface; nevertheless, since all the particles, or all the points in the surface, flow regularly over the surface, it follows, therefore, that also the vibration itself, although consisting of many points, is regularly distributed over the surface, just as if there were only one point. And the vibration runs the more quickly over the whole surface of the particle, in proportion to its tension and the greater central motion with which it is impelled.

Fig. 77.

The same is the case if the circumference is struck not in one place only, but in several; so that if it is struck on all sides by neighbouring particles, then the vibration once regularly started at several points extends throughout the surface and completes its course, just as if it had been touched in one point only.

116. The attenuated enclosed matter reacts and, consequently, the vibration is gradually diminished.

The greater the motion of the surface, as in the compressed particles of the fourth kind, the greater and more rapid the motion of the attenuated enclosed matter; and, consequently, the greater the reaction; so that the enclosed matter moved by the same gyration as the surface expands the surface, and consequently reacts, and strives to bring about the normal condition of the surface, and to obliterate all the motions that have arisen in it. Hence the attenuated matter reacts more strongly in such cases than in those where the motion is less. This also is the reason why the vibration is gradually diminished; and when it runs over the surface, it gradually vanishes. For the vibratory motion is bound to extend as far as the centre, and from the centre it then goes throughout the entire circumference. This motion rather tends to wipe out the vibratory

than promote it; consequently, it has hardly run its course before it has extinguished the motion that has arisen.

117. An undulation is a greater amount of vibration conjoined with the motion of the centre.

We have treated of vibration, which is nothing else but a kind of action and reaction of the periphery, the motion of the centre being stationary. But when the vibratory motion is so increased that the whole particle with its centre is moved from place to place, that motion is designated undulation.

It is evident from these things, that the terms vibration and undulation are thus applied respectively to the surface and the centre, or to motion in the surface or motion with the centre. For example, if there be any large vortex, as that of the sun, then if there be repercussion in the vortex itself, the sun or the centre remaining quiescent, then there is said to be vibration only in the vortex, although the particles of which the vortex consists have an undulatory motion. So also in the case of a particle which has other particles either in the surface or enclosed in it, if the surface particles undulate or even the enclosed particles do so, the larger particle may be said to vibrate; for it does not set up motion in its centre. Thus we understand by undulation that motion in a particle is set up at the same time as that in the centre.

118. A certain undulation is set up in the solar vortex and also in the planetary vortices by the sun's motion.

The sun itself, which is the centre of the large vortex, is filled with very attenuated matter, and, since it is closely surrounded with very light matter or particles of the third and fourth kinds, therefore it is not wonderful if it should continue to flow into that centre or solar ocean; but, since all that ocean round that centre is in motion, and carries all the circumfluent matter with it, which, continually but slightly resists, and continually tends to that centre because of its extreme lightness, therefore

it is not wonderful, that there is definite uninterrupted resistance and repulsion of the circumfluent matter. It also happens that new attenuated matter seems to flow continually through certain poles. For these reasons, therefore, the sun in the centre of the vortex acts like the heart or the lungs in man. So, too, it continually strives to remove from itself the circumfluent matter. Consequently there arises a definite motion in the centre of the vortex which, after the manner of an undulation, is dispersed thence throughout the whole of this vortex. Also a certain undulatory motion arises from the stars, which passes through their vortices and penetrates the vortices of other stars. In the same way fire sets up an undulatory motion in surrounding matter; for it always strives to enter it, but is unable, consequently a kind of undulation begins and extends throughout the whole volume, which consists of the same particles.

119. Particles of the third, fourth, and sixth kind are particularly suited to take up undulatory motion and communicate it to neighbouring particles.

There is no body or particle more adapted to take up and communicate undulatory motion than particles of the third, fourth, and sixth kind, to say nothing of those which we have hitherto treated. These particles came into existence and were made for such motion.

1. One rests upon another so that it presses on the surrounding particles by contact. For when the vortex is formed, and the motion tends from the centre to the periphery, or from the periphery to the centre, then one particle presses directly on another, or, from a certain effort and weight received from those above, one rests upon another, so that there is a continuous nexus, or an unbroken connection, which would not be the case unless, by means of motion, the matter constituting the particles was formed into a vortex. So great is the connection that one particle is continually pressed upon by another, and the more remote the motion is from the origin, the more the force of pressure is increased by the altitude.

2. Another reason is, that all particles of the third kind, as also of the fourth and sixth kinds, are perfectly spherical, so that there cannot be a form more spherical; for within is the attenuated enclosed matter, which plays the part of a vortex, and everywhere sends forth radii, as it were, from the periphery to the centre. In the surrounding vortex also radii are sent out from the surface to its exterior periphery. Consequently, the surface is very gently set in motion between two vortices which exert contrary effort; for the surface lies, as it were, in their womb and bosom. Hence the form is not only perfectly spherical, but also, because of the exceedingly rapid motion of the surface, the sphericity is subject to extreme tension; this is still more the case with a particle of the fourth kind. As a result, therefore, of these properties it follows that it is perfectly adapted to receive impact from every direction, and of communicating it with perfect regularity to those in the vicinity. Consequently, there can be nowhere a more perfect figure, for taking up such undulation than that which we find in particles of the third, fourth, and sixth kind.

3. Such particles are also perfectly equal, and of the same size in the same circles of their own vortex. For if there were inequality in the particles, one being greater than another, and thus an element were formed of greater and smaller particles connected irregularly, the undulation must necessarily become irregular. But since all the particles are perfectly equal, therefore they are completely adapted for communicating the undulatory motion which they have received to everyone and with perfect regularity. For although the particles in the vortex are compressed, and the lesser ones find an exit the nearer they are to the centre of the earth, still there is perfect regularity, because diminution takes place according to the distance stated; and because it is of the same amount in every circle of the vortex, the diminution by compression proceeding with perfect exactness.

4. In addition to this the particles are enclosed by vortices that are in perpetual motion; and, since the motion in all is

very rapid, and homogeneous, they very greatly assist contiguity; for directly one strives to enter the vortex of another, an undulation or movement arises on account of the motion of each.

Since, therefore, the said particles of the third and fourth kind, as well as of the sixth kind, are perfectly adapted, and, as it were, born and made for taking up and communicating undulation, therefore also, it is not to be wondered at that nature can so admirably sport with that undulatory motion, and by means of it produce such beautiful and delightful phenomena, of which we must treat when we take up the question of light and heat. And the more so because there can be no body in nature more perfect than these particles, which have a perfect uniformity of motion, figure, mass, weight, and position. Neither can a body or particle of any kind enjoy a more perfect elasticity.

It is known by experiment that spherical elastic bodies impart and take up the force of impact arising from the motion of adjacent bodies. If, for example, a single elastic sphere impinges upon another, both being in motion, each would take the force of impact or motion from the other, and each would impart its own force to the other. If one sphere were in a state of rest, and the other in a state of motion, the quiescent sphere would take up the motion of the other, and the sphere in motion would share the inertia of the other, and contrariwise. Similarly, if ten or a thousand or more such elastic spheres were in contact, one sphere would communicate its motion to the remotest sphere; two spheres would communicate their own motion to the two remotest spheres; and, consequently, the greater the primary motion, the greater the final motion in elastic bodies.

Since the particles of the third, fourth, and sixth kinds are perfectly regular and elastic, and maintain a perfectly regular situation, so that one undergoes pressure from many others, and with most perfect uniformity, it is bound to happen, that at the first impact, which, we take it, arises in the sun itself, the particles most remote therefrom, an opening having been given, will take on an undulatory movement; and this undulation will travel not by a definite fixed path to more remote parts, but

will proceed everywhere in all directions, so that it will extend itself as a sphere, and into all the surrounding surfaces, nor will it come to rest unless something retards the course of the undulation, or turn aside its course. It will be neither diminished nor increased, unless it enters into matter that is lighter or heavier, more distended or more compressed. We shall refer to this below.

120. An element which is subject to an impact, or caused to take up an undulation, does not undulate throughout the whole of its path, but only in that place where it has a definite opening, or where there is no obstacle that can resist the undulatory pressure.

We have stated in the preceding pages that the general undulation in our vortex arises from the sun's motion which strives to bring all the surrounding matter into synchronism with that motion. Still it cannot be said that all that matter which extends from the sun to us is urged into undulation, and that the undulating volume reaches as far as our earth. For if the whole atmosphere, or all the matter contained in the vortices were in a state of undulation, there would be a kind of infinite motion in which mutual disturbance would be set up, and contrary action and infinite collisions would take place there. This undulatory motion begins indeed from the sun or from another source, still it does nothing more than exert pressure upon the surrounding matter, so that it cannot be called undulatory motion, but only undulatory pressure.

But when something opposes the pressure, which gives way before the pressure due to undulation, so that there is no resistance in another direction, then first a kind of undulatory motion is set up, which derives its origin from the said pressure due to undulation. For example; if undulatory pressure meets a very thin membrane, which easily takes up motion, then it undergoes pressure on one part according to the impressed undulation, and thus it takes up a certain amount of

motion of undulation. For the membrane is of such a nature and so thin that the matter is unable to pass through or be turned back by pressure, unless it is moved by the pressure imparted to it. This, however, does not imply that there is a similar undulation and motion in the said element, but merely that the pressure is of a similar nature which is put forth when a corpuscle meets it which does not rest but yields to the pressure. So that if a certain part were void of matter, but everywhere surrounded with matter subject to a pressure that accorded with that undulation, then, at the farthest limits, or where that matter ends and meets with a vacuum, undulation and undulatory motion arises, and nowhere else. Just as is the case with water which undulates on the surface, the undulations being apparent to the eye. But this takes place because the surface of the water is acted upon by the lighter atmosphere, consequently the undulatory motion becomes visible in that place. But if such undulation originated in the depths of the sea it would extend only to a small distance ; elsewhere it would receive merely undulatory pressure.

In order to better illustrate this, let there be ten or a thousand elastic spheres arranged in order, and let an elastic sphere impinge upon the first sphere in the series, then the last or tenth or the hundredth in order alone takes up the motion and partakes of the undulation ; but not the intermediate ones, which remain perfectly quiescent, one pressing against another.

It follows from these things that an undulation has the same qualities as a bare pressure ; but what the nature of that pressure is in elements must be stated elsewhere.

121. Around the origin of motion there is some undulatory motion, but then it is merely pressure which runs out again into undulatory motion where the pressure ceases.

This proposition has been explained for the most part in the preceding paragraph. Now it cannot but happen that around the origin of motion, greater or less motion of undulation will

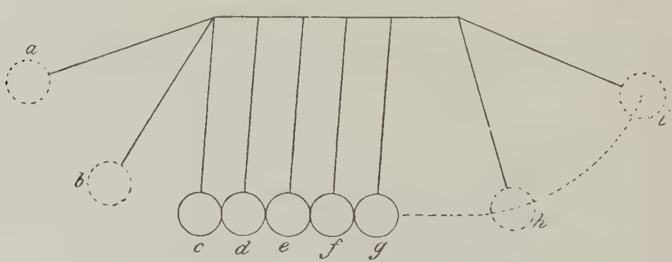
exist, but because of the elasticity of the neighbouring particles, they do not move far from their place, but the particles themselves undulating in their own surfaces, give place and yield; but they impart pressure to the rest, which pressure, like an impressed undulatory motion, is continued for an immense distance. That pressure then causes almost the same undulatory pressure in the place where something meets it which gives occasion for the pressure, as we have before stated.

122. There are greater and smaller undulations or degrees of undulation of very diverse kinds.

Here I do not yet speak of a diverse undulation originating at a distance which is traversed by pressure, nor of the diversity which arises from the varying magnitude of the particles, but of the diverse beginnings of undulations. For it is possible for undulations to be greater or smaller, according to the primary amount of pressure. For if a definite elementary volume is forcibly struck, a pronounced undulatory action will arise.

If an element had undulations imparted to it by that fiery ocean or sun, a somewhat forceful or pronounced undulation would result; and if the undulation were small the source or sun would be small. For the greater the magnitude of the source, the greater the pressure arising, and the greater the

Fig. 78.



undulation, where an undulation is capable of coming into existence.

The case would be like that of a number of elastic spheres (fig. 78), *cdefg*, which represent the structure of an element.

If the sphere h is dropped from the position h, then the last sphere in the series will not take a higher position than b; but if the same sphere be raised to i, and dropped from that position, then the vibration and impact will be greater; so that the last sphere c will rise to the position a; hence according as the impact is greater or less, or the place of origin higher a greater or less undulation will arise in the farthest limits, as also a greater or less pressure midway, as in *cdefg*.

Similarly, there will be a greater or less undulation, if it starts from several particles, or from a greater volume of them. If, for example, at h there were two or three elastic spheres, which impinged with a given force on a series of spheres *gfedc*, then on their part the two or three spheres would swing as far as b with the same force, and thus there would be different degrees of undulation according to the greater or less amount of the force of the primary impact.

123. The difference in the undulatory pressure is proportional to the distances.

Although such pressure or undulatory quality may be propagated to a very great distance, still the pressure is bound to decrease gradually, unless there is a cause at hand which either increases the pressure or renews it. Indeed the particles lie in the whole universe like an unbroken chain, so that there is nothing that is not touched by many of them at the same time; and that contact is exactly alike in all; nevertheless the pressure is greater if there is a greater incumbent volume. Since, therefore, the particles in their own vortices, are connected like a chain, it would not be wonderful if that pressure were extended to a very considerable distance; for the particles are extremely sensible to motion, touch, and pressure, as we have previously stated. Still, since the particles are elastic, the force of pressure must gradually diminish, especially if extended into a very ample space. Hence such pressure also may be diminished, and at length it may vanish, although the condition resulting from the pressure may continue for a very long time.

121. IF THE UNDULATORY PRESSURE IS PROPAGATED ACCORDING TO THE GENERAL PRESSURE OF THE VORTEX, IT WOULD SEEM TO BE AUGMENTED ACCORDING TO THE DIFFERENCES OF THE VOLUMES INTO WHICH IT TENDS.

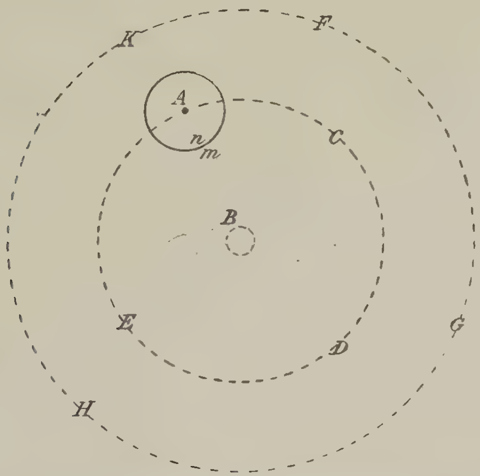
If we turn our thoughts to the consideration of the great solar vortex, and of the earth, we gather from the preceding considerations that particles are forced by the sun to all the peripheries of that vortex, so that there is a pressure directed toward the peripheries; and, consequently, the particles are pressed together. Since, therefore, there is such a pressure, and indeed a centrifugal pressure, it therefore follows that all the particles undergo pressure according to the distance from the centre, and consequently they decrease in magnitude, so that a particle near the sun is greater and more dilated than a particle near its remoter peripheries.

But in the vortex of the earth there is a pressure from the periphery towards the centre, and a kind of centripetal tendency, and, consequently, the particles there are subject to pressure. One particle rests upon another from the peripheries of the vortex to the centre; and therefore the particles nearer the centre are less dilated or more compressed than those which are at a great distance from the centre in that vortex. It is consequently especially evident what are the nature and connection of the particles from the sun to the centre of our vortex.

If, in fig. 79, the source of motion or the sun is in the centre of the great vortex B, because in it there is a certain centrifugal tendency, then one particle rests upon another, and is thus forced to the peripheries from B to K. Let A be the centre of the earth's vortex, or $ACDE$ the circle which the centre of that vortex will describe. In that vortex of the earth there is a certain centripetal tendency, and, consequently, one particle rests on another from m to n as far as A; and therefore, from the sun B to the centre of the earth's vortex A there will be a certain pressure which thus extends in a right line from the sun to the centre of the earth. The same pressure will be increased

in the vortex of the earth from m to A, since the pressure is not only according to the general pressure or that of the great vortex, but also according to the new or second pressure which the motion or pressure of the vortex itself causes. Consequently

Fig. 79.



it may be seen that the pressures extending from the sun to the centre of the earth are in the highest degree harmonious; nor is one contrary to another, but rather the one assists the other in handing on the pressure.

It follows, therefore, as a result of such mutual resting of particles one upon another, that the compression of a particle is greater, and that the particles are less in their order from the sun to the centre, in proportion to the distance through which that pressure or undulatory character directly extends.

Hence we see that the undulating pressure extends from the more dilated to the less dilated or more compressed particles; and, consequently, that undulatory pressure is taken up by the heavier volumes. On account of this quality nothing else can happen but the increase of the undulatory quality from the sun as far as the earth's centre. The particles themselves become less and less in proportion to their distance from the sun, and consequently they have greater velocity, and come more

into contact with those in their own neighbourhood. The elastic force also increases; for the less the particle, the greater its velocity; and, consequently, the greater the elasticity, the more quickly does the surface recover itself on receiving any impression. Also the volume of such particles becomes heavier; for the matter contained in a smaller, is the same as that contained in a larger volume, when the particles have been dilated. For these reasons it follows that the undulatory pressure grows and increases the more it extends from the sun to the centre of the earth.

But if the pressure takes the opposite path, it would seem that it gradually diminishes; nor is it propagated to the same distance with the same force.

125. The undulatory pressure of the elements differs from their general pressure.

There is a general pressure of the elements, because it is exerted toward the centre in the vortex of our earth, and also because that pressure extends spherically, so that there is an equal pressure upwards, downwards and laterally, according to the amount of pressure arising from the altitude. There are also other properties in the general pressure of the vortices which do not agree here with the undulatory pressure. But the undulatory pressure is propagated in a right line, and follows the radii which proceed from the source of motion; nor does it dissipate itself laterally or in another direction; but it takes a straight path from the given source. For there is no reaction; nor is a particle driven laterally or in a backward direction, as in the general pressure; but the action simply proceeds uninterruptedly along the radii or right lines from the source of motion. For if there were any reaction then that pressure would be like the general pressure; but there could not be such reaction unless a definite vortex were formed. From such a source of undulatory motion there could be formed no vortex that would run out into gyres and circles; but pressure without a vortex would be produced; and since the cause is not the

same, the same effect would not follow. Consequently such pressure, without the formation of a new vortex, or without a spiral or surface circulation, would proceed directly from the place of origin along radii running out into the universe. Nor would there be anything that could react or convert the pressure into any kind of reaction or turn it into all the directions that the surrounding particles might take.

126. Undulatory pressure is at once arrested by an opposing obstacle, nor can it get behind it, unless it can pass directly through its pores. The undulatory pressure is reflected at the incident-angle by any object which it cannot regularly traverse.

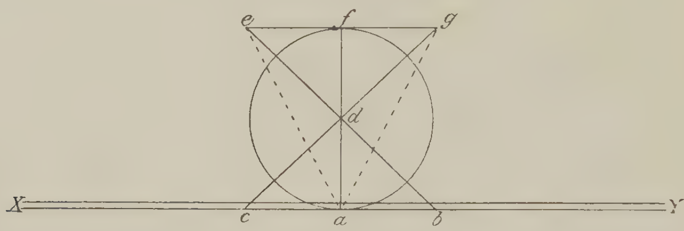
That the undulatory pressure is at once arrested by an opposing obstacle is a consequence of what has been previously stated; for since there is no reaction or return pressure on the part of the particles; or since there is a general similarity of pressure, and since the pressure takes place along right lines and along radii from the source of motion to the peripheries, it also follows as a consequence that it stops there, if there is an opposing body, and that there is no such pressure in the rear of the opposing body. For if there were reaction in the undulatory pressure, or if the undulation formed a kind of vortex, in which there was a centrifugal or centripetal tendency, then there would also exist an undulatory pressure behind the body; but, according to what is stated in the preceding paragraph, such pressure is absent where there is no capability of traversing the body.

But if the opposing body is such that matter can pass through it, and such transmission can take place regularly, then also the said pressure or undulatory influence may extend to the rear of the body.

That undulatory force or pressure can be reflected from an obstacle according to the angle of incidence is quite evident from experiments both in physics and mechanics, such experiments, or laws being capable of geometrical explanation. For example

let (fig. 80) there be a suitable particle of the third, fourth, or sixth kind, this being so small that the lines *gc* and *ga* would be practically parallel as seen by us, for the part subtending the angle *g* would be almost negligible. Let *XY* be the object on which the particle impinges, that is, let it be carried from *g* to strike the

Fig. 80.



opposing body at *a*. When it impinges at *a*, in consequence of the elasticity of the body, the particle will be reflected by the resilience of the opposing body, therefore it tends to take the perpendicular path *a* to *f*, and also the horizontal direction *a* to *c*. As a result of being opposed, it takes two directions, one from *a* to *X* horizontally, the other from *a* to *f* perpendicularly. Since the impact takes place at an angle, therefore the force along the horizontal line *aX* to the force along the perpendicular *af*, is as *fg* to *fa*, according to the well-known rule in merchanics. Consequently, when the particle endeavours to proceed from *a* to *X* under the influence of the force *gf*, and strives to proceed from *a* to *f* under the influence of force *fa*, it follows that these forces are compounded and that it proceeds in the direction *ae*; for $fe = fg$. Therefore the diagonal is *ea*, whence the angle *eaf* is equal to the angle *gaf*; that is, the angle of reflection is equal to the angle of incidence.

Since, then, the particle is forced from *g* towards *a* and remains under pressure, on an opening being given, it immediately exerts pressure upon the volume of particles along the given direction, and is reflected at the same angle at which it impinged.

127. There may be many thousands of such undulatory pressures in one volume, nor will one impede another; but each pressure will complete its own undulation when the opportunity is given.

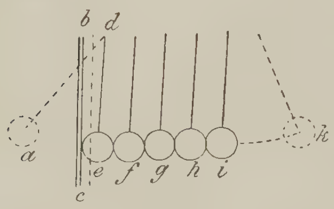
In the preceding pages we spoke of the sun as the sole source from which the undulation proceeds into all the circles and parts of its vortex, and which also sends its undulations into the vortices of its planets or orbs. But here I assume that there are a thousand such sources, or suns, as there are many thousands of stars which are like suns in their vortices; but they appear to us to be less luminous and smaller by reason of their distances. Besides in our vortex there may also be many sources of motion. As, for example, if there are fires in many places, so there will be reflection from thousands of places. For when an undulation is reflected from objects and at the angle of incidence, then reflection may take place at a thousand places; and not from a thousand only, but from an infinite number, from which an undulation started by the sun is reflected and modified, and although such undulation proceeds from such infinite sources, still it is able to give rise to regular undulatory pressure in that elementary matter.

It is clear from these things, that elementary particles are not urged into any undulatory motion, but that instead of motion there is undulatory pressure or influence, which passes into undulation if there is nothing to prevent it, or if a body comes into contact with them, which is capable of being impelled to take up such motion. It is clear also that this pressure, arising from so many sources, is distributed without disturbance among the particles, so that if the pressure on a particle is from above or below, at any angle or laterally, that particle takes up such pressure and communicates it to the neighbouring particles in a right line, the radii therefrom extending to all the peripheries. The particle is thus under pressure in every direction, still it will not move unless there be opportunity or an opening.

In order to see this illustrated, consider fig. 81. Let *efghi*

represent a collection of particles, placed here simply in a straight line. If *k* impinges or oscillates against the series, then all in that series will remain in their normal position except the last, *e*.

Fig. 81.



If any obstacle is in the way, as *bc*, so that the globe *e* cannot depart from its position or oscillate, then it remains where it was. But if the obstacle is removed, then *e* will fly off to *a* under the influence of the same undulation as *k*. If the obstacle is thin, like a membrane of some kind, then it takes up that pressure, the membrane, however, cannot remain quiescent, but takes up the said undulation. Consequently, the last particle cannot undulate unless it is free so to do; but if nothing prevents, then it immediately acts in agreement with the undulatory motion. It follows, therefore, that only the first and last particles in the series manifest the effect of the undulatory motion, the intermediate ones remaining stationary.

Similarly, if the small spheres do not lie in a right line, but are grouped in a volume of globular form, then, if the undulatory motion affects such volume at one or a thousand points, the particles forming the volume will suffer pressure at a thousand points, and they will be at rest under such pressure; but if an opening occurs at any part, the particle will be affected by that undulation which is strongest, and which proceeds from the opposite direction. The remaining pressures will be exerted, but with a difference.

But in regard to the taking up of the undulations, as to whether this takes place in a very thin membrane, or where an opening occurs, many points worthy of consideration might be brought forward. For instance, one little membrane might be able to take up a thousand undulations; one undulation without any impediment might pursue its path through the undulating part of another membrane, so that one undulating part might be able to pass to the rear of the undulating parts of a thousand

others. For an undulating membrane must be considered just as tense and even tenser than if it were not undulating; indeed it will have greater tension than if unaffected by any undulation. Hence, although the membrane is not flat but curved, still many other parts in the same membrane may be able to propagate waves, just as if the membrane were stretched or flat.

The same is the case with the undulatory pressure of particles of the fourth and sixth kinds. A volume may be variously subject to pressure, and the pressure may then run out into an undulation, when opportunity offers; and, indeed, with variety, because the pressure or undulation of one impedes the pressure or undulation of another. But we must treat separately concerning undulation in membranes and in solid bodies.

128. Particles may be variously reflected from solid bodies, if they are of regular form.

When some particle under pressure from an undulation falls upon a flat surface it rebounds or is reflected at the angle of incidence. But if, when still under the influence of undulation and after reflection, it falls upon another plane surface, it will again be reflected at the angle of incidence; and the same will be the case on third and fourth reflections.

It consequently happens that this pressure, because of diverse reflections and inflections, turns out to be exceedingly varied, and

Fig. 82.

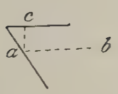


Fig 83.

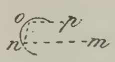


Fig. 84.

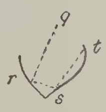
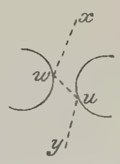


Fig 85.



sometimes it becomes so mixed that hardly any regular reflection is able to exist. For example, consider fig. 82. If the undulation or pressure proceeds from b to a in a straight line, but is received at an angle at a, then it is reflected thence to c according to the angle of incidence, and at length goes on its way. If

the undulation, fig. 83, proceeds from m to n, from thence to o, and so to p, then it is twice reflected before it proceeds on its path. If, as in fig. 84, the undulatory pressure proceeds from q to r, thence to s, and so to t, then it is clearly further reflected, and another modification of the undulation takes place. So also if the undulation proceeds after various reflections have taken place. As, for example, in fig. 85, if it tends from x to w, then from w to u and leaves from the other side. So too it may undergo reflection so as to leave in a direction opposite to this. Such variations may be infinite, and the more there are the more will be the varieties of pressures in the volumes, and the varieties of phenomena appealing to our senses, and the more sources and origins of undulations will there be. But more on this subject when we treat of experiments and the mechanical means for experiments.

129. THE REGULARITY OF THE PORES IN OPPOSING BODIES IS THE CAUSE OF THE PASSAGE OF AN UNDULATION; IRREGULARITY IN THIS RESPECT LEADS TO THE CONFUSION AND DISAPPEARANCE OF UNDULATIONS.

That an undulation can proceed from the sun, and pressure from the sun be maintained through so great a distance as to our earth, arises from the perfectly regular arrangement and connection of the particles. For if the particles were not exactly alike, and their arrangement perfectly regular, neither undulation nor pressure could be transmitted through so vast a space. Therefore, when any object or body offers opposition, in which there are pores having such regular arrangement that the order of the particles cannot be disturbed without the undulatory pressure being propagated in another direction, then such pressure will be transmitted, although suffering diminution on account of the regular bodies which oppose it. But if the pores are irregular, so that the pressure or undulation which is transmitted passes on irregularly, then pressure does not make itself manifest elsewhere but is lost, as it were, although the particles themselves are quite able to transmit it.

130. This undulatory pressure is the cause of sight, light, and colour.

This undulatory pressure extends uninterruptedly from the sun to our earth. And because on the earth there are various forms, a variety of greater and smaller bodies, various kinds of salts, earths and metals, and a diversity in the form of their minute parts, therefore undulations are bound to be differently reflected, and, on being so reflected, to strike against the membranes of the eye. As, therefore, there is in light nothing which cannot be explained by the rules and mechanism of undulatory pressure, and nothing in undulatory pressure which cannot be observed in light, and nothing in light and undulatory pressure which is not received in the eye or organ of sight, therefore all these things are shown to be true when they are compared experimentally with the principles themselves and with our theory. Here we can deal with these in a general manner only, a more particular knowledge depends on experiments and the comparison of these with our theses.

Moreover, if you examine and explore the bodily sensations you will see a kind of mechanism extending throughout the whole body, and particularly in the case of the eye, which co-operates to take up undulation by means of the senses. How great is the number of nerves in the body, and how numerous their interlacings and connections, one supporting and helping another! How manifold are the membranes everywhere concerned with the nerves themselves and the bones also! What attenuation and continuity, what intercommunication among the membraneous coverings of the brain! What expansion of these by means of the blood-fluids and nerves, and what colour do those fluids possess! As to the eye itself, its structures lie outside the skull and are made evident by radiating fibres, as it were, and protected also by various coverings.

Since, then, the extremely attenuated coverings of the brain, the pia mater and the dura mater, extend to the radiating fibres in the eye, the most minute undulations must be taken up by the

membranes and retina of the eye, just as undulations of greater amplitude are taken up by the drum of the ear. If then you could see the structure of the membranes of the eye, and those concerned with more subtle organs, you would be amazed to perceive that the whole arrangement is nothing but a mechanism for the taking up and distributing the waves that impinge on the membranes. Here you would find a field in which you could examine the mechanism of more subtle undulations, and investigate the paths and courses of the more subtle sensations in the human body, and discover how that mechanism extends beyond the limits hitherto assigned to it.

Nevertheless, it can be said that in the senses there is nothing but a kind of mechanism which is adapted to receive undulations, with this difference that one organ is able to take up the undulations of a more subtle element with its particular variety, while another can take up undulations of greater amplitude. Consequently in the corporeal system we find not one but many membranes. The bones are invested with their own membranes. In the ear there are the stirrup, the hammer, and the anvil for communication with the drum, the cochlea for dilatation, and the nerves for conveying the undulations of the air to the coverings of the brain, and then from these to the entire nervous system.

131. UNDULATORY PRESSURE AFFECTS THE SMALLER PARTICLES WHICH FLOW BETWEEN THE LARGER ELEMENTARY PARTICLES; AND IT IS NONE THE LESS EXERTED ALTHOUGH THE LARGER ELEMENTARY PARTICLES FLOW BETWEEN.

As to the undulation, or this undulatory pressure, it is not in the air-particles, for the undulation acting in these is grosser, and pertains only to the organs of hearing, where it is taken up by grosser membranes. The undulation, or the undulatory pressure which is the cause of light or the sensation of sight, belongs, however, to particles of the sixth kind, which have been very greatly diminished and compressed in the neighbourhood of the earth. In fact this kind of undulation arises in the sun, and extends thence to our vortex by means of particles of the

third and fourth kinds. But if it be considered that this undulation, or this undulatory pressure, increases very greatly while it is passing from the sun to our vortex—for it proceeds from expanded and lighter particles to compressed and heavier particles—then it follows that this pressure has undergone such great increase that the particles of the third kind, which are in the vortex of our earth, press forcibly upon the particles of the sixth kind, which are true particles of our vortex, and are designated under the common name of particles of the ether. And when the pressure becomes so great, the undulatory pressure is bound to be transferred to and be communicated, as it were, to particles of the sixth kind. Let us, therefore, regard them as being subject to undulatory pressure.

132. If an undulation is deflected by some object, and, even if it tends in another direction, still the eye can only conceive it as proceeding toward itself in a straight line; by such pressure vision is very largely, but naturally, subject to deception.

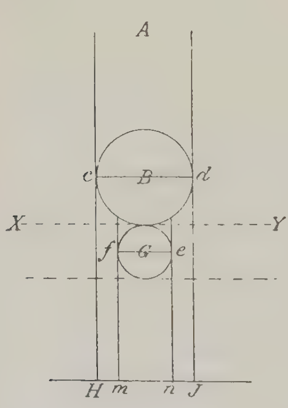
Undulatory pressure tends to proceed along a straight line from the source of the undulations, hence undulatory motion is in the source itself only. As, for example, in the eye undulatory motion takes place in those two extremities only, the optic nerve or the extremely subtle membranes of the eye, and nowhere else; intermediately there is nothing but undulatory pressure which proceeds by a direct path to the eye from the source of motion. When, therefore, this undulatory pressure is refracted in the manner previously stated, so that the angle of incidence is the same as the angle of reflection, then the pressure at the point of incidence is the same as in the path of incidence, and in the path of reflection proceeding from this point. Since, therefore, an undulation is perceived only along a right line, then that source of motion is bound to be seen along the right line, as is evident in the case of mirrors. For the vision cannot be deflected along a curve or angle; and the pressure is the same at the point of incidence as at the point

of reflection, and further the particle or the volume of particles subject to pressure which represents the line of reflection is the same as those which represent the line of incidence. Consequently the eye supposes everything it sees to lie in the same line. And so our vision is subject to illusion, and the eye sees shade as light, and takes what is fictitious for what is genuine.

133. A BODY EXISTING IN AN ELEMENT WITH SMALLER PARTICLES IS AMPLIFIED, IF SEEN BY THE EYE WHICH EXISTS IN AN ELEMENT CONSISTING OF LARGER PARTICLES; AND THE AMPLIFICATION TAKES PLACE ACCORDING TO THE DIFFERENCE BETWEEN THE PARTICLES IN THE MEDIA, AND CONTRARIWISE.

Suppose a body or object placed in a medium or element which consists of smaller particles, and suppose the eye placed in the same element, then there can be no amplification. Nowhere can the undulatory pressure be interrupted or turned from its path, consequently the character of the undulation in the organ, or in the nerve of the eye is according to its nature in the source or origin; as for example if an object and the eye be conceived as placed in the air, or in the ether, or in water, etc. But if the eye were placed in one element, such as the air, and the object in another, such as water, then the undulatory pressure would undergo refraction where the elements met, or where the light passes from one element into another. Of reflection we must treat in the following paragraph, here we can deal only with amplification.

Fig. 86.



It is well known that any object placed in water appears to be larger when viewed by the eye situated in the air. This arises from the diverse magnitude of the particles. For example, in

fig. 86, let the magnitude of the water particle be represented by G, and let its diameter be fe; let the air particle be represented by B, and its diameter by cd; and the surface separating the water and the air by XY, the upper portion being air, the lower portion water. Let the object placed in the water be HJ, and let the eye in the air be at A. When a ray passes from the object to the surface in G, or to the particle of water lying in the surface, then part mn of the object ought to be seen at f and e. But since the larger particle B occupies the higher position, whose diameter is cd, therefore the radius or undulatory pressure cannot proceed directly upwards on account of the upper particle, nor can it pass through the particle; but the matter in which the undulatory pressure is propagated flows around the air particle, consequently it ought to appear at c and d, so that the pressure which was at f and e is now represented at c and d, whence part of that object is enlarged; and this varies according to the differences between the particles; that is, as fe and cd or as the diameters, or the areas of the particles. Hence the amplification varies with the medium, for example, oil or spirit, etc., instead of water; and when mn equals HJ. The contrary would be the case if the object were in the air and the eye in water; or if the object were viewed by means of a mirror placed in water, the eye being in the air; for then the object would appear to be smaller, and in fact there would be a variation according to the differences between the particles, as previously stated.

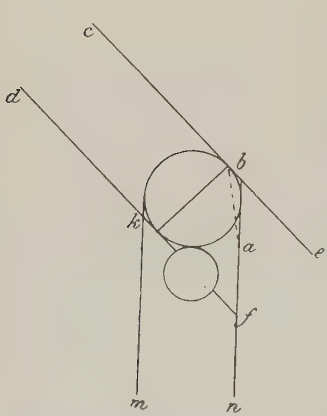
As, therefore, the optic nerve cannot take up the pressure of one particle of ether[1] or one undulatory pressure, but a definite volume consisting of many particles, and an infinite number of particles of the sixth kind, therefore the amplification must be considered as an aggregate of such particles, whose volume is extremely minute so as to be able to affect the optic nerve.

[1] The original is *æris*, but it should evidently be *etheris*. See no. 131.

134. A BODY IN WATER OR ANY OTHER LIQUID HAS LESS APPARENT ELEVATION WHEN THE EYE AND THE OBJECT LIE IN THE SAME PERPENDICULAR; BUT MORE WHEN THE EYE AND THE OBJECT ARE SITUATED IN A LINE THAT FORMS AN ANGLE WITH THE SURFACE.

In the previous paragraph we discussed the amplification of a body placed in various media, from these also as a consequence its apparent elevation can be deduced; see the figure in the preceding paragraph. For when the undulatory pressure appears at *d* and *c*, which otherwise ought to appear at *f* and *e*, then there is amplification. When also in the same way the altitude of the particle increases, and the diameter of the particle of air is greater than the diameter of the particle of water, then when it appears at *d* the radius has a greater apparent elevation than if the particle *G* were in the place of the particle *B*; whence the amount of the apparent elevation of the body in water is proportioned to its amplification; for the cause is the same. It is supposed, however, that the eye and the object are in the same perpendicular line.

Fig. 87.

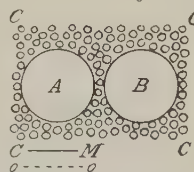


But if in fig. 87 the eye were at *dc* and the object at *mn*, then the undulatory pressure would appear at *k* and *b*, and *ba* would be still higher; for the pressure proceeds along the right line from *a* to *b*, so that the apparent elevation is greater than a semidiameter, and still greater if the angle is greater. There is also another reason, of which we shall speak in the following pages.

135. Great pressure or undulation in particles of the fourth kind gives rise to a small pressure or undulation in particles of the sixth kind. On the contrary, a small pressure or undulation in particles of the sixth kind gives rise to a great pressure or undulation in particles of the fourth kind.

We have stated before that the matter in the tellurian vortex consists of particles of the fourth and sixth kinds, consequently diverse phenomena arise if particles of the fourth kind or of the sixth kind are put in motion. When, therefore, particles of the fourth kind are fluent among particles of the sixth kind, then, on account of the great difference existing between particles of the fourth and sixth kinds, there is also difference between the motions or pressures. In fig. 88 let *A* and *B* be particles of the sixth kind, *CCCC* those of the fourth kind, then I say that, if the particles *CCCC* of the fourth kind undulate, in such a way that the undulation is of considerable amplitude, then also the particles of the sixth kind will be able to undulate, but such undulation will be of small amplitude.

Fig. 88.



For example, let the undulation be of such amplitude as to extend from *C* to *M*, then the particle or the volume of such particles of the fourth kind will appear to undergo considerable movement, and that, indeed, through a space which equals twenty, a hundred, or a thousand times the diameters of a particle. By such an undulation also an undulation may be set up in *A*; but the undulation thence arising will be small, being equal only to one diameter or half a diameter; for the undulation of particles must be reckoned according to the diameters.

On the contrary if a particle of the sixth kind has a small undulation, as for example if *A* or *B* undulates to the extent

of half a diameter, that undulation is only small in reference to that particle; but by means of such undulation the particles of the fourth kind can be excited to motion, and, indeed, into waves of the same amplitude; but since this space is equal to a hundred or a thousand diameters of such a particle, that undulation may be regarded as of considerable amplitude, that is, in respect to that particle.

Therefore it follows, that one or more particles of the sixth kind can be moved by a volume of particles of the fourth kind, and, on the other hand, by the motion of one or two particles of the sixth kind, some hundred particles or a volume of particles of the fourth kind can be moved.

When we speak here of undulation, it must be understood that we mean also undulatory pressure, for if it is effective and strong —which can become an undulation when the opportunity is given —then a considerable pressure may communicate a slight pressure to particles of the sixth kind; and, on the contrary, a slight pressure in particles of the sixth kind produces a considerable pressure in particles of the fourth kind; for that pressure is undulatory in character, so that it takes the form of waves immediately the opportunity is given. We see from these things how undulation or pressure in one element is able to be communicated to another element, and in proportion to the diameters of the particles.

136. A SLIGHT PRESSURE OR UNDULATION IN PARTICLES OF THE FOURTH KIND CAUSES MERELY A VIBRATION IN PARTICLES OF THE SIXTH KIND; OR A VIBRATION ARISING IN PARTICLES OF THE SIXTH KIND SETS UP AN UNDULATION IN PARTICLES OF THE FOURTH KIND.

This is a consequence of what has been previously stated. For an undulation is the reciprocal motion of a particle, the particle itself being moved together with its centre; but a vibration is motion in the surface of a particle, which takes place without affecting the centre. If, therefore, an undulation in particles of the fourth kind be so slight, that it undulates only to the

extent of one of its diameters, then in particles of the sixth kind no undulation can be set up, and consequently the whole particle cannot undergo a change of place; but every part of the surface can be moved, so that merely a vibration is the result.

On the other hand, when a particle of the sixth kind begins to vibrate, then even a very slight undulation can be set up in particles of the fourth kind. It is the same with pressure or undulatory and vibratory quality; for when opportunity of passing into an undulation is given it does so, the said pressure or quality meantime setting up undulatory motion remains.

137. VIBRATION IN PARTICLES OF THE FOURTH KIND CANNOT IMPART ANY VIBRATION TO A PARTICLE OF THE SIXTH KIND.

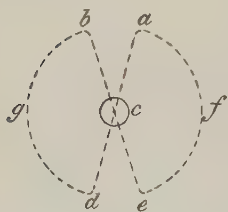
A vibration in a particle of the fourth kind, which is confined merely to the surface, can have no communication with a particle of the sixth kind, so as to be able to set up a vibration in it. For there is such a difference between the surface particles of the fourth and sixth kinds, that one cannot be moved by another. But it must be confessed, that if a considerable vibration occurs in a particle of the fourth kind, a very slight vibration indeed may be imparted to a particle of the sixth kind and the reverse; but then the amount of vibration in a particle of the fourth kind must be very great for a very slight vibration to arise in a particle of the sixth kind.

138. THE SURFACE OF A PARTICLE OF THE SIXTH KIND, BY REASON OF COMPRESSION, MAY BETAKE ITSELF TO THE CENTRE, AND THERE FORM A SPHERE, AND BECOME LESS AND LESS, WHENCE THERE ARISES A PARTICLE OF THE SEVENTH KIND.

We have said that a particle of the sixth kind has a surface of the same kind as a particle of the third kind, with a difference only in the size of the surface particles. For the surface particles in a particle of the sixth kind are particles of the fifth kind; and the particles in a surface of the third kind are points of the

first kind, but in regard to the surface itself, and the movement of particles on the surface, it is the same in each case. So that a surface particle of the sixth kind flows spirally and forms polar cones just as a particle of the third kind does; hence also it possesses the same characteristics, that is, it can be compressed to smaller dimensions, and the surface matter may pass through the polar cones to the centre and by degrees form a kind of globe, which gradually increases in size from the increase of surface matter, turning out at length to be like a particle of the fourth kind, with the difference only that it is larger, and surpasses the former sufficiently in magnitude. There is no need here to say how the diminution arises, if compression operates; for we have previously stated this in connection with the description of the particle of the fourth kind.

Fig. 89.



In fig. 89 let *abgdef* be a particle of the sixth kind. If it suffers compression, the surface or part of the surface immediately passes through the cones to the centre, the central sphere *c* being increased, and the size of the particle diminished. From this it is quite clear that a particle of the sixth kind can be very greatly diminished, and indeed from a diameter of a thousand units to a diameter of one unit, so that if the diameter of the larger is a thousand units, the diameter of the smaller may be one unit, or less. For the particles in the surface are very small, as we have previously stated in the case of the particle of the fifth kind. Hence, when the whole surface passes into a single small globe, it may become quite small, so that such a particle may be more and more diminished, even to more than the thousandth part of the surface; and, consequently, in the duplicate ratio to the body itself of the particle, or to the volume of the particles.

Since, therefore, a particle may be so compressed, it would not be remarkable if the difference in their magnitude differed to such a degree that the diameter of this particle with such an

origin measured 900, 800, 700, 100, or 50 units; and that the particles should be so dissimilar as to be incapable of comparison as to magnitude.

In regard to compression, we must consider that the particles in the earth's vortex exercise mutual pressure along the perpendicular, and that that compression is everywhere the same. Since then, there is a centripetal tendency in the vortex and the particles rest one upon another, so that one particle exercises weight-pressure upon another, attended, nevertheless, with a circular and spiral motion, it would not be wonderful if the surface matter fell toward the centre, and thus became a particle of less size, yet kept up its own motion among the remaining particles, and preserved its own spherical form. Hence, since it is the nature of a vortex that causes compression, and compression begins in the surface, and continues toward the centre, therefore this particle becomes less and less, until at length, near the centre, it becomes the smallest possible. There are, then, very great diversities of magnitude in this particle.

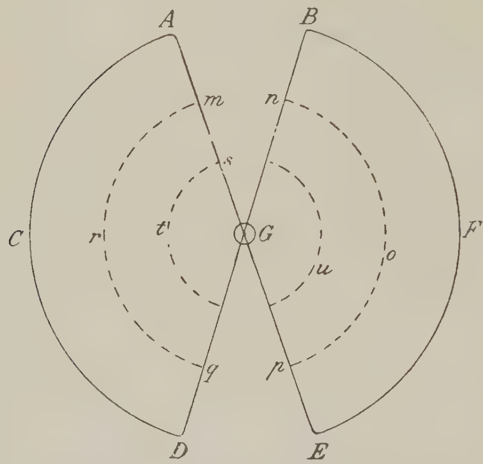
Since, then, the particle of the sixth kind is compressed, and forms a kind of little globe at the centre, either less or greater, merely a kind of globe is formed at the centre, and takes up its position there; therefore, we designate such a particle a particle of the seventh kind. For it differs from a particle of the sixth kind in both magnitude and other characteristics. Here, then, we have the origin and form of a particle of the seventh kind, and also its magnitude, which is very diverse from the rest.

139. A COMPRESSED PARTICLE CAN UNDERGO EXPANSION, AND THE SMALL GLOBE AT THE CENTRE, AS TO EITHER THE WHOLE OR PART OF IT, MAY PASS TO THE PERIPHERY.

The particle of the fourth kind may be contracted and its surface diverted to the centre, and, in fact, it may flow through the polar cones to the said centre, and also leave this for the surface; consequently a particle of the fourth kind, having been once contracted or lessened in size may undergo amplification, or return into its original form. The reason for this can

be seen from the centre of this particle, and from the form of the particles contained in the central small globe.

Fig. 90.



From our theory in regard to what we have stated before, it follows that the attenuated matter or that of the second kind is in the cavity of the particle of the sixth kind, so that a circular or spiral motion arises from and is perpetuated by this matter. But the surface of this sixth kind of particle consists of particles of the fifth kind, which are like those represented by fig. 92. From these particles, which constitute the surface, the central small globe found in the particle of the seventh kind is formed, and constitutes there a central small globe, as in fig. 92; so that it consists of almost an infinite number of such particles. These particles (fig. 92), or the surface particles of the sixth kind, are of almost the same magnitude as the exceedingly mobile particle of the second kind, or of the surface that constitutes the particle referred to. It follows from this, that the attenuated matter which is in the cavity of the particle of the sixth or seventh kind may also exist between the particles of this small globe (fig. 92), or between particles of the fifth kind. For since they are of the same magnitude, they can be together with, and in the same small globe. These things being granted, let (fig. 91) be a particle of the seventh kind much compressed;

Fig. 91.

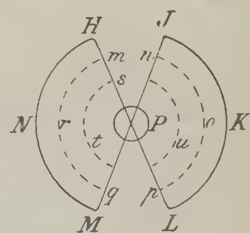


Fig. 92.

therefore, it also has a larger enclosed globe, and, consequently, the surface of a particle of the seventh kind, as in fig. 91, describes more revolutions in the same time than a particle of the same kind (fig. 90), although there is the same velocity in the surface. But because the surface is less and the velocity is the same, therefore, more revolutions are completed in the same time. We have previously treated on this point. Consequently, when the pressure is diminished, that is, when a particle of the seventh kind, is not under great pressure from other incumbent or neighbouring particles, then the attentuated enclosed matter and the very rapid motion of the surface causes it to be so enlarged that one particle is nevertheless in contact with a neighbouring one, but when the particle is amplified, the rarified matter in the surface remains, nor does it cohere so well, as to prevent it from being dissipated by the attenuated matter of the second kind. Hence, on account of the amplification, the enclosed matter of the second kind becomes rarified, and, consequently, it cannot act as before upon the central small globe, and, as it were, compress and hold it together. Hence it follows that the same attenuated matter as that which exists between the particles of the fifth kind or between the particles of the central enclosed small globe (fig. 92) is able to act upon the very particles of the small globe, and that it can drive these from the small globe, and very forcibly urge them into motion by a second similar point, and, therefore, through such motion in the cavity of the particle, cast them out to the surface again. So that it may be still better understood how matter of the fifth kind, which is in the sphere of the seventh kind of particle, can return. For as soon as the surface is increased, the pressure of the neighbouring particles being removed, the motion of the enclosed matter is diminished, for this enclosed matter becomes less, and the greater part of it keeps itself in the neighbourhood of the surface, or becomes rarified throughout the whole surface. It hence follows that there is less centripetal tendency in that particle, and that the central small globe suffers less repression. In this condition the enclosed attenuated

matter is able to exercise its force upon the particles of the small globe, and to scatter them one after another, and urge them into a very rapid motion, and so drive them to the surface; and when they come to the surface they repair and restore it where it is wanting. Then new surface matter accrues from the central small globe, which under pressure again returns to the centre through the polar cones. Consequently, compression or constriction of the particle as well as amplification are possible.

For example, in the particle of the seventh kind (fig. 91) let the attenuated matter referred to be represented by *mnopqr* and *sut*, when the surface is increased under diminished pressure (for the surface is increased immediately as the pressure is diminished, since the motion of the particles is in the surface between two vortices, one within, which tends to the centre, and the other without, which tends from the centre to the periphery, hence the surface lies as it were in equilibrium; and the compression being less, and there being a continuous motion of the surface, that surface will be ejected from the centre to the larger periphery, and thus amplify the body or itself), then the same attenuated matter remains, but is more rarified as *mnopqr* and *sut* in fig. 90; and I maintain that new attenuated matter still enters through the poles. The distance, however, from the surface to the centre is greater, and consequently the effect of the vortex or centripetal tendency round the centre is less; for it flows throughout a greater space; hence the matter enclosed in the particles of the central small globes gives rise to a certain force, so that it is able to separate these, dissipate them throughout the cavity of the particle and drive them toward the surface.

140. A VOLUME CONSISTING OF PARTICLES OF THE SEVENTH KIND BECOMES HEAVIER THE MORE THE PARTICLES ARE COMPRESSED ; AND IN CONSEQUENCE OF THE DIFFERENCE IN WEIGHT AND MAGNITUDE, IT GIVES RISE TO DIFFERENT CHARACTERISTICS.

Consider figs. 90 and 91 of the preceding paragraph. If the volume consisted of particles similar in magnitude to those represented in fig. 90, it follows therefrom that a volume of such particles would be very light ; for they would be large and expanded. Hence also a volume consisting of such large and expanded particles must necessarily be extremely light. But if the volume consisted of particles such as those represented in fig. 91, it follows that they must be heavier and more ponderous. And the matter in the particle of fig. 90 is the same as that in the particle (fig. 91). For the surface matter has gone to the centre and remains there ; whence if two volumes were of the same magnitude, but consisted of particles of a different kind, that is, dilated and compressed, one would be light, and another heavy, and they would differ in these respects according to the compression of the particles. Hence one may conclude that a volume of particles in the extreme or highest part of a vortex is exceedingly light, since the particles there are very greatly dilated ; but in the lowest part of a vortex or near the centre, the volume is very heavy, because there the particles are much compressed.

Since the volumes, although the particles are of the same kind, that is of the seventh kind, differ in lightness and heaviness, as the particles themselves differ in magnitude, therefore they take on diverse characters ; the undulatory pressure in the compressed or heavier particles may be stronger and more active, the communication of their motion more rapid and lively. There are many other considerations of which we must treat elsewhere.

141. A PARTICLE OF THE SEVENTH KIND CAN BE COMPRESSED TO SUCH A DEGREE AS TO BECOME NOTHING BUT A KIND OF SMALL GLOBE, THAT IS, IT CAN BE COMPRESSED INTO A QUITE SMALL GLOBE, WHICH WILL BE SMALL IN COMPARISON WITH PARTICLES OF THE SIXTH AND SEVENTH KINDS, WHENCE THERE ARISES A PARTICLE OF THE EIGHTH KIND.

We have treated of this small globe enclosed in a particle of the seventh kind in the previous pages, and also of the matter of which it consists; there is no need, therefore, to deal with it any further; for it consists of particles of the fifth kind. But because the particle of the sixth and seventh kinds can undergo very great pressure, therefore, when there is great pressure, such as exists in the centre of the vortex, then it can undergo pressure until the whole surface vanishes, and with the surface, which was in continual motion, the enclosed vortex. Then at length a small globe arises which wholly puts off a vortical character, and remains a definite hard particle, having no such quality as we have been considering in previous particles, except in those of the fifth kind.

As to the size of this small globe, it is small in comparison with the particle from which it has arisen. For a particle of the fifth kind, which forms the surface of the sixth and seventh particles, is so small that it only equals a particle of the second kind. Consequently, since the surface consists of particles so attenuated, the small globe so formed is bound to be small; for the more rarified the surface so much smaller will the small globe turn out to be, so that the diameter will be scarcely a thousandth part of the dilated particle.

This particle so originating, and, indeed, at the centre of our vortex, is designated a particle of the eighth kind.

142. When a particle of the seventh kind becomes compressed into a small globe or into a particle of the eighth kind, which takes place at the centre of the earth, particles of the fourth kind remain enclosed among such small globes.

We have before said that this compression of particles of the seventh kind so as to become particles of the eighth kind happens in a place where the force of compression is very great; for it results from two causes. The first is the pressure of the incumbent particles of the sixth and seventh kinds; consequently, also, on account of the height of the column, the volume of such particles in the lowest part, or near the centre, undergoes pressure, just as is the case with the air, which exerts pressure according to its own weight; that is, one particle rests upon another, and thus weighs upon another. The second reason is that surrounding particles of the fourth kind also exert pressure, and do so according to there altitude, that is, according to their distance from the sun. Hence when particles of the seventh kind are under pressure, so that a small globe is produced, it follows that the said particles of the fourth kind cannot escape; and they therefore remain and maintain their position among the particles or globules of the eighth kind, so that they mingle with particles of the fourth kind, which also do not differ much in magnitude from them.

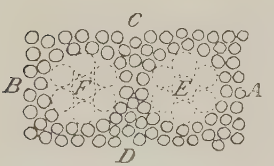
143. From the motion of the particles of the fourth kind among the particles of the eighth kind there arises a spherical body (bulla) which constitutes a new particle; this we designate a particle of the ninth kind; it is the same as the air particle.

It has been shown that particles of the eighth kind, or the small spheres referred to, could not exist, unless there were particles of the fourth kind between them, the latter having a vortex formed of attenuated matter within and also without;

consequently, they cannot exist without motion. But because the attenuated matter always acts upon the surface of particles of the fourth kind, therefore they can never be at rest, but must be in a continual state of motion. Therefore, although they lie enclosed between particles of the eighth kind or between those small globes, they are, nevertheless, capable of being moved. Therefore these small globes cannot but be urged into definite motion as a result of the motion of the particles of the fourth kind.

For example, in fig. 93, let *ABCD* be the small globes referred to, or the particles of the eighth kind, *E* and *F* particles of the fourth kind enclosed within them. These, because they cannot be without motion, although lying enclosed within, always act upon the volume of the small globes, and at length impel them into the same motion as themselves; and so from that continual motion they form a surface and the spherical body in which lie enclosed particles of the fourth kind which impart motion to the surface, this surface now consisting of such small globes or particles as are designated those of the eighth kind. Hence we have a new particle, which we may call a particle of the ninth kind; and this particle is identical with the air particle. Thus, then, we have arrived at our elementary matter.

Fig. 93.



Since then, such a particle has arisen not far from the centre, and since it is heavier and larger than those of which we have already treated, therefore it forms the surface of the earth. It is greater because the surface particles here are greater, and the enclosed matter is a particle of the fourth kind; and this much surpasses in magnitude the particle or the attenuated matter of the second kind. If, then, such a particle could come into equilibrium with the particles of the seventh kind, it must certainly be larger, so that a certain volume of particles of the fourth kind might be enclosed. We shall deal further with this subject below.

144. Air, or the particle of the ninth kind, is subject to exterior pressure by three forces, that is, by particles of the fourth, seventh and ninth kinds. But interiorly it is under pressure of particles of the fourth kind, which are more compressed than particles of the fourth kind which exert pressure from without.

Here we must state how the air particle, or that of the ninth kind, is kept together. This results from the pressure of the matter within and the pressure of the matter without. For unless it were under pressure in both directions it could not subsist. But if there are two pressures, it follows that the surface of such a particle can be maintained and the particle itself remain intact; just as vapour whose surface consists of water. But because this is under the pressure of a kind of fluid matter within, and exteriorly is subject to the pressure of the air, therefore, the surface maintains itself and the vapour continues intact. It is the same with the aërial spherical body, which has air within and without.

This air particle is subject to pressure from without, not merely from particles of the fourth kind which flow around on every side. This pressure is sufficiently great, because particles of the fourth kind constitute the matter which is everywhere present extending from the sun throughout all the solar vortices to the limit of the great vortex. Consequently, the first external pressure arises from matter of the fourth kind. The second pressure is due to particles of the seventh kind; for these particles constitute the true matter of the tellurian vortex. Therefore, since this matter begins at the extreme part of the vortex and continues toward the centre, where it is reduced by pressure to small globes, of which the surface of the air consists, therefore, there is a second pressure upon the external surface of the air particle, that pressure increasing from the surface of the vortex as far as the centre of the earth; consequently a pressure sufficiently great, arising from this matter,

exists. The third pressure arises from particles of the ninth kind, or from the homogeneous air particles themselves. For every element possesses weight in itself, and the weight increases in the direction of the earth according to the altitude. So, too, air possesses weight, for one particle rests upon another; and since they all tend towards the centre of the earth, therefore the higher presses upon the lower, or a higher volume upon a lower volume. This is evident also in the case of air. Hence air is subject to its own pressure; and from the air the greatest pressure exists, particles of the ninth kind being heavy enough to produce this. Consequently it is plain that air in elevated places possesses great rarity and undergoes expansion—which is evident from countless experiments—but in lower places it is subject to pressure and undergoes contraction.

But as the air in its interior cavity is subject to pressure from particles of the fourth kind, so that they form a kind of counter weight, it would not be remarkable if they underwent still greater pressure than those of the fourth kind that are on the outside. For enclosed particles of the fourth kind exert the pressure toward the interior surface, just as the particles of the fourth, seventh and ninth kinds simultaneously do upon the exterior surface, the pressure of the former being equal to the pressures exerted by the three latter particles. But in the surface of the atmosphere, where the third pressure does not exist, the interior parts experience less pressure than in the lower part of the atmosphere.

Also it follows that the enclosed particles of the fourth kind have less size because they are more compressed than the particles of the fourth kind which are outside, because they are less compressed. We may see also from these things how the particles of our atmosphere are held together in such a way that they cannot be rent asunder. For each element exercises its pressure equally in all directions. So, too, enclosed matter of the fourth kind exerts a pressure equally distributed on the concave surface of the air, while particles of the fourth and seventh kinds, flowing exteriorly, exert a

pressure equally distributed in every direction on the convex surface of the air.

145. ALTHOUGH AN AIR PARTICLE UNDERGOES COMPRESSION, AND BY COMPRESSION BECOMES LESS AND LESS, STILL IT RETAINS ITS SPHERICAL FORM, AND PRESERVES ITS OWN MOTION AMONG THE EQUALLY COMPRESSED PARTICLES.

Here again another kind of particle is capable of being formed. For there is an air particle which is not compressed by its own air particles, and another which is compressed. But as the designation air is sufficiently well known, therefore we may call them air particles, whether expanded or compressed.

One can hardly wonder that, although such being the form of the air particle, it yet retains a spherical form; and even when several air particles surround it, that the sphericity of the particle persists. But in order to explain this, and that it may be thoroughly understood, we must observe in the first place, that the external pressure is exerted by means of particles of the fourth and seventh kinds, and that the internal pressure is also exerted by means of particles of the fourth kind, so that there is both an interior and exterior pressure. And although the particles are externally subject to pressure, still there is an equilibrium between the internal and external pressure. Consequently, the sphericity remains whatever may be the pressure. Just as when little bladders of air are formed whether at a great depth in water, or near the surface, they nevertheless preserve their spherical form. So in the case of this particle, it is subject to pressure both internally and externally, and there is an equilibrium in the pressure.

It might be supposed that a kind of inequality will arise in the particles of air when they are subject to much pressure from neighbouring particles, so that there are unequal depressions in the convexity, either because the spherical form becomes octangular, or is subject to pressure by many other particles; but this happens when such pressure is exercised by neighbouring particles, which possess weight, in such a way that the particle

subject to pressure is passive, as it were, and can merely offer resistance to the given pressure. But here it is different; for one particle undergoes pressure from another and then refers both to the particle causing the pressure and the particle subjected to it; all the neighbouring particles are therefore subject to the same pressure. Therefore, as the pressure is gradually increased in the whole volume of the atmosphere, this whole volume is subject to pressure, and not each particle selectively. Each particle does indeed undergo pressure, but from the neighbouring particles which are subject to the same pressure. Hence I do not see how one particle can be forced by another into any other than the spherical form. For it happens that the exterior particles are of diverse kinds--the ninth, the seventh and the fourth, and granted such pressure, then there is equiulibrim between the exterior and interior particles. Also the interior particles are so small that they can exert pressure on each point of the surface, exterior particles of the same kind reacting.

Since, therefore, by whatever exterior pressure the interior particles of the fourth kind are compressed or diminished, they always retain there sphericity; and, consequently, since the interior particles of the fourth kind always retain their compressed state, which equilibrates with the multiplex external pressure; and since they remain unimpaired in form, it follows, therefore, that there is an equal pressure in all directions within and without; and then the pressure tends everywhere to a spherical form.

But if the pressure arose solely from the homogeneous particles of the ninth kind; and if there were an element within which could not be compressed; as, for example, in the case of spheres, or bladders filled with water, then the pressure would be found to give rise to other than a spherical form. But there is another reason. Since the interior particles of the fourth kind become less from compression, in agreement with the law of external pressure, then there can be no other internal pressure than that which is equal in all directions in the cavity of the

particle; therefore the air is spherical in form, although it undergoes very forcible pressure externally.

146. The surface of the air particle is moved interruptedly by interior particles of the fourth kind, but by neighbouring particles most advantageously along the equator; and in the air particle there is a double motion.

The enclosed particles of the fourth kind maintain a polar position; for in them there are polar cones; and these are kept continually in a direction toward the mundane pole. But we have said previously that in particles of the fourth kind that position is not so accurately observed, since with particles of the sixth kind they are in the same vortex and motion, consequently, they are able to move in a circle, but still they lapse into their own position. Hence included particles of the fourth kind preserve their polar position in every motion whatever, consequently they can be driven round about. But since the enclosed matter strives after the said position, therefore, when certain revolutions have been completed, they return to that position. But in the air particle, or that of the ninth kind, we have to consider a double motion. The first is that which is induced by the surface itself. For the surface can be in motion while the enclosed matter is quiescent; because the motion of the surface of particles of the fourth kind acts upon the surface of a particle of the ninth kind, so that it is caused to move in a circular manner; and it would seem also that this motion is likewise spiral, and proceeds along the path or fluxion of the matter in the surface of particles of the fourth kind which are enclosed therein; for it follows perfectly the motion which the moving particles possess. But a second motion is possible, that of the surface itself together with the enclosed matter; these being conjointly moved. For a particle is capable of exerting influence in a twofold way—the surface itself, when it is moved as a whole and also each particle can have its own motion; in the same way as the earth itself moves

on its axis, while minute creatures and every kind of living thing move about on its surface. So, too, a ship is borne along on the ocean, while the sailors on board move about hither and thither. Similarly an air particle can revolve, and yet every particle in its surface can have its own motion, their motion appearing to be the same as the motion of the particles of the fourth kind contained in the surface, which is spiral.

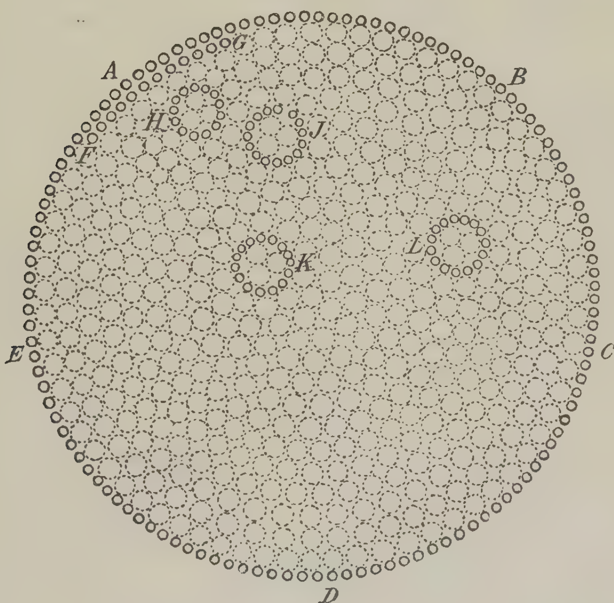
There is another motion of the whole particle, by which the enclosed particles also are moved, not, however, with different motion; hence according to what we have laid down the whole particle is moved circularly and in all directions, still it is most fittingly carried along the equatorial line or circle; for the particles of the fourth kind, both those within and those without, tend to a polar position, whence, when they circumgyrate along the equator, they have no need to strive to preserve their situation, but they remain, as it were, in a natural situation. For when the particles are turned in another direction, the enclosed particles of the fourth kind must necessarily be turned; also the more the motion departs from the equatorial circle, the more must the particles be subject to change of revolution. Hence the natural revolution of this particle is along the equinoctial. Nevertheless, the particles of the surface itself move according to a spiral gyration, of which we have frequently made mention.

147. IF A PARTICLE OF THE NINTH KIND SUFFERS COMPRESSION, THE COMPRESSED SURFACE FALLS TOWARD THE INTERIOR PARTS, AND, BY ENCLOSED MATTER OF THE FOURTH KIND, IT IS FORMED UP INTO NEW, BUT SMALL PARTICLES.

We have shown that a particle of the ninth kind or the air particle consists of a simple surface, and that it has particles of the fourth kind within and also without. But when this particle is subject to pressure, so that the surface falls toward the interior, that is, when the surface begins to be duplicated, then, I say, those particles of the surface which are forced toward the interior, become spheres of a less size under the influence of the enclosed matter. The reason for this is the same as in the

previous case. Those surface particles of the air particle, when they are under pressure in every direction from matter of the fourth kind, are then able to continue intact; for they receive as much pressure in one direction as in another; consequently, the surface rests in a state of equilibrium; and the surface particles, as if in their own natural state, move about the suface. But in truth, when any part of the surface falls

Fig. 94.



toward the interior parts, so that some surface particles are separated from their surface and, consequently, experience pressure from the enclosed matter, but not from the external matter, then that matter, or the enclosed matter of the fourth kind, acts upon them, just as it previously acted when the air particle was formed.

In order to have a better idea of this let us consider fig. 94. Let *ABCDE* be an air particle with the enclosed particles of the fourth kind. If the one undergoes compression so that the exterior surface is driven toward the interior, or folded as in

FG, then there is no pressure without; so that the particles *FG*, which are carried towards the interior, have their equilibrium disturbed, or the pressure to which they were subject, consequently, the matter of the fourth kind acts upon them, because they are, as it were, in a free state, and they are, as a result, caused to assume the form of small particles, such as *H*, *J*, *K*, *L*. The reason for this has already been given—they lose their equilibrium, being relieved of pressure from every direction, when they come within the periphery, and are consequently rolled up into smaller particles, as *H*, *J*, *K*, *L*, which float, as it were, in the larger particle; and by expansion and compression they maintain themselves in a kind of equilibrium. In these smaller particles the same matter is enclosed as in that of the particle of the fourth kind; nor can they be diminished or become greater unless the matter enclosed in the air particle is dilated or compressed.

Here we see how the air particle can be restrained and compressed, and whither the surface matter betakes itself in compression. For the matter remains the same however much it is contracted, the weight of the volume being increased in that proportion. If there is considerable compression, a hundred or more particles may be formed, and the whole cavity filled by them. The reason is as just now stated, that such particles must be compressed both exteriorly and interiorly, and otherwise lose their equilibrium, these alone being unable to be present in particles of the fourth kind; for the former have no motion, being small and heavy; while the latter are exceedingly mobile, larger, and extremely light; consequently they do not come together in one volume, unless they fall upon some surface, undergo pressure in every direction, and thus constitute a particle. This could also be shown geometrically if it were worth while.

148. These new enclosed particles that have originated from surface matter of the air particle, are carried now toward the centre, now near the surface, according to another motion of the air particle.

These new particles formed within the air particle are, indeed, in a state of equilibrium within the particle, nor do they tend upward or downward; for the pressure within is equal to that without in its first formation. If, therefore, the air particle were at rest and without motion (the surface particles can nevertheless be the subject of motion, the enclosed matter being quiescent), then they could neither fly to the centre nor, elsewhere, tend toward the lower parts; and when the air particle begins to be lightly moved, then they flow hither and thither, now to the centre now to the periphery. But when the air particles begin to be somewhat forcibly put in motion, and, in fact, along the equatorial circle, then, because these particles are somewhat heavier than the enclosed matter of the fourth kind, they are projected toward the surface, and there take up their own position. So that they are carried by a more forcible motion from the centre toward the surface, just as heavy bodies are when enclosed in a rapidly rotating cylinder.

149. When the air particle expands, then these enclosed particles also expand and are dispersed, and return to the expanded surface of the air. A portion of them does not suffer dispersion unless the air particle is dilated to the amount of pressure to which these particles are subjected.

First, we have spoken above of the formation of the new particles contained in the air particles, that is, that they are formed when the surface matter is forced inward, and the particles are compelled to betake themselves into the cavity; for then such particles are not the subjects of equilibriating pressure; consequently, they are again rolled up into small particles of the kind described; and those have originated from the air itself. It follows,

therefore, that some such particles are formed when the air undergoes slight pressure. But the number of particles becomes still greater, the greater the pressure, and more still when the pressure is very greatly increased. For example, if the diameter of the air particle is ten units, then, if the pressure reduces it to nine units, new particles are immediately formed within the cavity. If the pressure still increases so that the diameter is eight units, further particles are produced, and still more if the pressure is continued, the diameter of the air particle becoming seven, six, five, four, or one unit.

These things being granted, it undoubtedly follows, that the enclosed matter of the fourth kind suffers pressure to the same extent as the air particle itself. For example, if the air particle is reduced from ten units to nine then the enclosed matter of the particle of the fourth kind alone undergoes pressure, that is, each particle of the fourth kind, or its diameter, is reduced by pressure from ten to nine units; so, too, if the air particle is compressed to eight, seven, six, five, four, three, two or one units, then also the diameters of the included particles of the fourth kind undergo pressure in the same proportion, so that the pressure of the enclosed matter of the fourth kind is the same as that of the air itself.

If, therefore, these new air particles within the air particle possess also the same matter as that of the particle of the fourth kind, as those which were formed in the first degree of compression, that is, when the diameter of ten units is reduced to nine units, then those that are formed under that pressure possess this enclosed matter, this being reduced, as to diameter, from ten to nine units. Moreover, those particles formed when the air is still more compressed, say to eight units, have then enclosed matter of the fourth kind compressed to the same extent, similarly those smaller particles which arise under still greater compression. So in one air particle there are many such particles which hold within them matter of the fourth kind differently compressed.

But, in fact, when the air particle is compressed, then the

matter enclosed in the air particle—I say nothing of the matter of the same kind enclosed in these new and small particles—throughout the whole cavity is subject to the same pressure; and it exercises pressure upon the concave surface of the air particle, and also upon the convex surface of these new particles. If the pressure is greater without than within, then they are able to remain intact and unbroken; but when the air undergoes expansion, then the matter of the fourth kind enclosed in the air particle is expanded, and, consequently, does not exercise an equal pressure upon the convex surface of these new particles; but the matter enclosed in these new particles exercises an increasing pressure; so that the equilibrium in them perishes and they consequently collapse, and recede to the dilated surface of the air particle. But they do not all collapse, but only those which are formed under the same pressure as that to which the air particle returns.

For example, let the air particles expand from one to two units, then all those new particles formed when the pressure was one unit are broken up. Or if the air particle has its diameter increased from eight units to nine, then all those small particles which were formed when the amount of pressure was eight units are dissolved. If the expansion still increases, say from nine units of diameter to ten units, then all those new particles are broken up which were formed when the force of compression of the air particle reduced the diameter of the air particles from ten to nine units. Or still more clearly, if the expansion of the air particle rises from one to six units then all those new particles are dissolved which were formed when the diameter of the air was reduced from six units to one unit; but not those particles which come into existence when the compression of the air particle reduced the diameter from ten to six units; these are first broken up when the particle has its diameter increased from six units to ten units by compression, and so forth.

Immediately those particles dissolve they recede to the surface of the air particle, and form a connection or series with them. Whence it follows that the more dilation takes place the more will

there always be an unbroken surface consisting of particles of the eighth kind. For as in the state of contraction a surface existed, so will it be in a state of expansion, the same amount of particles will find a place in the surface of the air particle when there is the same amplification; whether in a state of contraction or in a state of expansion.

150. BECAUSE THE AIR EXERTS PRESSURE ACCORDING TO THE HEIGHT OF ITS COLUMN, THEREFORE ITS PARTICLES ARE MORE EXPANDED IN THE HIGHER PARTS OF THE ATMOSPHERE THAN IN THE LOWER. NEVERTHELESS, THE AIR PARTICLES MAY BE MUCH EXPANDED IN THE LOWER REGIONS OF THE ATMOSPHERE, AND YET A COLUMN IN THE UPPER REGIONS OF THE ATMOSPHERE MAY EXERT UPON THEM THE SAME PRESSURE AS THAT BY WHICH THE NEIGHBOURING PARTICLES ARE CONTRACTED BY GREAT PRESSURE; AND THE CONTRARY.

The air particles are subject to a threefold force as previously stated, which they undergo from particles of the fourth kind, but that pressure can give rise to no contraction; for the particle suffers the same pressure from the same matter within as without, so that equilibrium is maintained, unless, therefore, other matter is added, from which it may undergo pressure, I hardly know whether they could subsist. Hence the pressure is exerted by another force from the matter of the particle of the seventh kind; and by a third force arising from the homogeneous particles of the air, so that they undergo pressure according to the height of the column. This can, in fact, be proved mechanically and by the help of considerable explanation, but it would be superfluous to discuss these matters, since there is no difficulty in demonstrating them; besides, we must defer this matter until we have proved that the pressure is proportional to the altitude in every direction, and also proportional to the base and opening; and there are many things which can be made clear by experiments which we shall put off for special consideration.

It is clear from these things, that the particles in the surface of the atmosphere are very much expanded, so that the diameter of one air particle there measures many units; and it can be shown that the diameter of a particle there is hundreds of times greater than the diameter of an air particle near the earth; but this fact must be proved by experiments.

But in the atmosphere near our earth air particles can be expanded by a certain force, and yet undergo pressure from those above them just as if they were not expanded. For if particles of the fourth kind, which are external, are moved or urged into motion, so that they undergo expansion, it follows as a consequence that their state of equilibrium is changed, and that the enclosed matter of the same particle of the fourth kind also becomes expanded, and carries with itself in that process of expansion an air particle, or that of the ninth kind.

If, for example, enclosed matter of the fourth kind suffers greater compression than that which exerts pressure exteriorly; and if the latter is expanded, then it follows that the enclosed matter undergoes expansion, and together with that the surface of the particle of the ninth kind, although the particle of the ninth kind supports pressure from the particles that rest upon it just as if it were not expanded. Also we must add, that particles of the ninth kind may be driven into very rapid motion, and, consequently, may force all the enclosed matter with those newly-formed particles to the periphery, and expand it by a certain force. Hence we see that a particle of the ninth kind can be expanded not only in the surface, but in the centre, or in the lowest part of its column. But as the cause is different, therefore, the effect arising therefrom is different. Of these things we must treat in our theory experimentally and in dealing with special subjects.

151. If a particle of the ninth kind is too greatly expanded, its surface may be disrupted; but the surface matter set free and disrupted will pass into the surfaces of other particles of the same kind.

If a particle of the ninth kind be too much distended, whether in the highest region of the atmosphere, where there is no pressure from particles acting from above, or even in the lowest region from other causes of which we have spoken in the previous pages, it will happen that there will be a defect of the surface matter, so that the surface will not be continuous. Consequently, it follows that the enclosed matter of a particle of the fourth kind will be able to burst forth through the interstices, or otherwise, since the pressure outside is not sufficient to counteract the interior pressure, it will be unable to be kept in the regular surface; consequently, such a particle will be broken up, and as it were, vanish completely. Hence this surface matter or that of the eighth kind will be dissipated, and will only be able to find a place in the surface of lower particles, which surface it will increase; so that a heavier particle will exist and have a greater amount of surface material, which will fall toward the interior parts, and form the new particles, of which mention has already been made. Again, such a particle can be more expanded than that which has collapsed, and of which we have spoken, so that it can be expanded to such an extent as to be hardly capable being of broken up.

It is clear from these things that particles in the highest region of the atmosphere are capable of being distended, so that their diameter may be greater than the diameter of a particle of the same kind in the lowest region by hundreds or thousands of times. For it is evident that such a particle is increased by much matter through the collapse of other particles in the neighbourhood, in which there was not so great an abundance of matter. A particle, therefore, in the highest region, hundreds or thousands of times greater, may have ten times

more matter than a particle in the middle or lowest region of the same atmosphere.

It follows, therefore, that by such disruptions and collapse particles may be formed which can be no further broken up by any amount of expansion; for in them there is a sufficiency of matter to form a bar to any disruption.

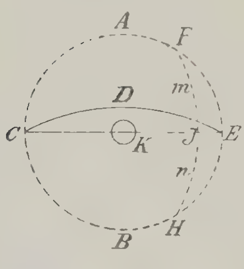
152. THERE MAY BE PARTICLES OF THE NINTH KIND IN THE MIDDLE AND LOWEST REGION WHICH DIFFER BOTH IN WEIGHT AND SIZE; BUT STILL, AFTER AN INTERVAL, THEY MAY GRADUALLY BECOME EQUAL IN BOTH WEIGHT AND SIZE.

Since, now, particles of the ninth kind may be broken up by too great an expansion, and since such expansion may take place not only in the highest region, but also in the middle and lowest regions of the atmosphere, therefore the surface matter may betake itself to other particles in the vicinity, and augment their surface. Their weight will, consequently, be increased; so that the weight of some particles will be greater than that of others; and there will be certain differences between the particles. Since, however, some are heavier, they cannot be aptly moved with other particles in their vicinity, but are driven to another part, being thus separated from others to which they are dissimilar. In the same way it will happen that one particle will be larger than another, either because one is more expanded than another, or because there is within a greater abundance of matter belonging to particles of the fourth kind. But since the motion of one particle does not entirely synchronise with the motion of the rest, therefore, after an interval they will be driven thence; for both the pressure and the motion itself offer an impediment; consequently, anything so dissimilar to, and out of harmony with, the rest will be driven thence, nor could they continue for any length of time to exist together in one volume. Equality of the motion itself acts in such a way that such a particle will be thrust either up or down, and the volume deprived of it.

153. Inequality of form in the tellurian vortex arising from unequal pressure of the circumfluent matter gives rise to inequality of the moon's motion, the ebb and flow of the sea, and also to various states of the air and its storms.

Much variety exists among particles of the ninth kind; sometimes they are less and sometimes more compressed; whence the volume of their particles is sometimes heavier, sometimes lighter; and aqueous vapours arise according to the weight or lightness. But if we consider the form of the tellurian vortex, we shall see that many things may be deduced which give rise to variety in the volume of particles of the ninth kind. As to the form itself, it is not exactly spherical, but because that vortex is borne in the great solar vortex, it is carried round, in a kind of stream as it were. For it is well known that the great solar vortex is carried round along the ecliptic, and that the whole vortex is carried round in that direction—the vortices of the planets too are borne on such a stream; but since they are separated from the matter of the great vortex, so that such vortices as are fluent in the greater vortex are distinct both in motion and matter, as we have before shown, therefore they do not follow the stream of the greater vortex by their own fluxion, but they are compelled to follow the stream, just as a ship, forced to move in a certain current, follows the current, but there is a continual action against the stern or back of the ship; so, too, the vortex of the earth moves indeed in that vast current, but yet this stream acts continually on one part.

Fig. 95.



In fig. 95, let *AEHBC* be the earth's vortex, *CDE* the ecliptic, *EKE* the equator; let the stream act continually against the side of the vortex at *E*. Because the pressure is there, therefore also the vortex will alter its form, nor will it be any longer exactly

spherical. On that side it will become flatter, as *FJH*, so that the diameter of the vortex on the side toward the earth *K*, that is, *JK*, will be less than on the other side *CK*. Since, therefore, it is evident that the form of the vortex is not everywhere spherical, but flatter on one side, it follows that there is great variety in the volume of particles of the ninth kind. We will here enumerate briefly the various classes :—

1. In spring and autumn the vortex undergoes pressure in its middle part. That is, the greatest pressure then exists around the equator, as is evident from the figure, and, consequently, it is less at a more remote distance from the equator. The reason of this is that the ecliptic then cuts the equator ; or one point of the ecliptic is on the equator.

2. In spring there is the greatest pressure at a distance of 23½ degrees from the equator, and it is above, and, consequently, exercised equally towards the ecliptic poles. Hence in summer the pressure varies according to its distance from the equator. It differs also, in respect to the inhabitants, from spring and autumn pressure.

3. In winter the pressure is greatest at 23½ degrees from the equator, so that the vortex experiences the greatest pressure when it is at the stated distance of 23½ degrees below the equator ; consequently, it follows that the pressure then is less above the equator than at any other time of the year, and therefore the pressure will vary in respect to the inhabitants of the earth.

4. The moon which, together with its own vortex is borne along in the earth's vortex has its own motion and follows the stream of this vortex. As seen by us it seems to pursue its course unequally, for at one time it is in perigee and at another in apogee, at another time at a middle distance. The cause of this is, that when the moon is at quadrature, as in *J*, then it is nearer the earth than when at *C* and consequently in perigee, and differently when in apogee. The perigee also differs according to the times when it arrives there. For if the moon were distant from the equator to the extent of 23½ degrees, so as to be then in the lowest or highest part of the ecliptic, the apogee would

be less than if it were near the nodes, or near the equator. For, unless the altitude of the moon from the equator when at quadrature were observed, it would be impossible to determine the apogee. But when the moon is new or full, then the moon is carried along very uniformly or equably.

5. Since, therefore, the moon is carried along unequally when in its quarters, that inequality will be found to be increased when the time of the year has to be considered ; that is, whether it is summer, winter, or autumn. Then, too, in respect to the moon, another distance at once comes into consideration. For example, in winter, when the pressure is greatest at a distance of $23\frac{1}{2}$ degrees under the equator, let the moon, at the same time, be at its greatest altitude, or $23\frac{1}{2}$ degrees distance above the equator ; whence at 47 degrees the moon is removed from the maximum pressure of the vortex, and consequently is in its perigee. But because it is so far removed from the maximum pressure, its perigee is not so exact, because here the moon proceeds as though it were not in its perigee. But if the moon were in winter under the equator at $23\frac{1}{2}$ degrees, then it would be in its maximum perigee.

6. What is here said of perigee must also be understood of apogee, which is in the other or opposite position. For the pressure in this direction is proportionately extended to other parts. But since the matter of the vortex does not go wholly to the opposite place, but also proceeds laterally, therefore the moon's apogee does not withdraw in the same proportion as its perigee approaches.

If, then, the figure of the earth's vortex were examined, and compared with the pressure of the large vortex, then our knowledge of the moon's motions would become easy, this knowledge offering such difficulties in calculation, that the place of the moon by observation and calculation is scarcely obtainable when it is at quadrature. Let it be considered at full and new moon ; for there it is at a middle distance from the earth, then the matter is easy, its motion at that period being equable.

But because the cause of apogee and perigee is not yet known, it must be deduced from observations; so that there may be error in its determination. We see here what the true cause is, why perigee varies at different times, so that we can scarcely declare that it is in perigee, when nevertheless it is. Another time it is in its greatest perigee or apogee. If these things are rightly weighed, the moon's motions can be easily explained. But because it is not our purpose to describe the moon and its course, but simply to investigate the form of the elementary particles; and because the quality of the particles much depends on this —which will be seen in the following pages—therefore I can simply give a general idea of this matter, otherwise I might develop the conception and geometry of these matters more fully.

In regard to the ebb and flow of the ocean, this is thought to arise from the moon's pressure, and this opinion is held, since it coincides with the motion itself of the moon. But if we went into the real origin and cause of this phenomenon, we should see that the true cause is to be found in the inequality of the vortex; for when the form of the vortex is irregular then there is inequality of pressure. Matter of the sixth and seventh kind exercises pressure according to the altitude of the vortex. Hence, when the vortex is higher in one part than in another, at a time when the moon is at its quadrature and in perigee, the flow of the tide will be least; for the pressure is least there; also the altitude is least, as JK, fig. 95; but at another place the pressure is greater and the altitude greater; but these vary according to the moon's position. When the moon is at JK, being then endowed with a definite vortex, it occupies a certain position, and, consequently, increases the height of its vortex in that part, and when this happens there is greater pressure in that direction; whence the pressure exercised by the moon alternates and varies. The real cause is in the altitude of the vortex, which is less on one side than on the other.

The reason why the air undergoes a certain alteration through the inequality of the vortex is this. The pressure exercised by

matter of the sixth and seventh kinds is less in one place than in another. The less the altitude the less the pressure, and the contrary; therefore the pressure is less in one place than in another; consequently, the pressure varies. This pressure is not exerted on the volume of particles of the ninth kind, or on the atmosphere itself, but on each particle of the ninth kind. For the air, or a particle of the ninth kind, undergoes pressure from particles of the sixth and seventh kind, hence that pressure is exercised upon every particle of the ninth kind, or the air particle. When, then, the air, or each particle of the air, is under pressure, it follows that each particle of the air undergoes pressure, and, consequently, becomes less; and thus the volume becomes heavier as the particles become less.

If, then, the altitude of the vortex is great, considerable pressure and contraction of the air particles result; but where the altitude is less, then there is less pressure, and a certain expansion of the particles results. But here the moon intervenes. For if the moon is moving in its perigee the vortex in that direction immediately becomes higher, and, consequently, there is a greater pressure of the particles than if the moon were away; and still greater if the moon were in apogee. This pressure of the particles of the ninth kind also varies according to the time of the year. In spring and autumn the altitude is least near the equator, and greater laterally. In summer the greatest pressure is at $23\frac{1}{2}$ degrees distance from the equator towards the north; in winter the pressure is greatest at $23\frac{1}{2}$ degrees distance from the equator toward the south; hence the pressure of the particles varies in different regions.

There are various reasons for the changes in the weather. *First*, there is the diverse form of the earth's vortex, whence there arises a diversity of altitude, and a diversity of pressure of the particles of the sixth and seventh kinds, which exert a pressure individually on every particle of the ninth kind or the air particle; for they do not exert pressure on their volume, but separately.

Secondly, the moon increases its column in the vortex wher-

ever it comes, whence the vortex undergoes a variation in respect to the moon.

Thirdly, the altitude of the vortex in autumn and spring, is different from what it is in summer and winter.

Fourthly, there is one pressure of the moon in apogee or in perigee, another also if the moon is at its greatest altitude from the equator or elsewhere. This variety depends much on the compression of the particles of the ninth kind and their expansion.

For if the column of the earth's vortex is higher, then the particles of the sixth and seventh kinds will be subject to greater pressure, and, consequently, will become smaller; the particles of the ninth kind will be compressed as a result, so that they too will become smaller. This variety gives rise to variety in the weather, so that it is now rainy, now calm; now the mercury rises, and now falls; and many other phenomena besides.

We must not indeed omit to remark that the sun by its rays and motion contributes much to variety in the weather. For when the motion springs up in particles of the fourth kind, then the particle of the ninth kind undergoes expansion, and thus the sun may act contrary to the vortex. There is some action also arising from the reflected light of the moon, but it is slight.

If these causes are well understood, I trust that the weather phenomena may be able to be investigated, and the reasons for the rise and fall of the barometer may be able to be explored; as also some of those evidences which appeal to our senses, or are afforded by chemical experiments, or that are seen in the constitution of our bodies. There are many other matters which I feel must be passed by now.

154. The particles of the ninth kind are subject to an undulatory pressure just as are the particles of the sixth and seventh kind.

If the origin and source of undulation is in the volume of particles of the ninth kind, then no other undulation exists

around the particles of the sixth and seventh kinds than that which has already been considered. An undulation begins if some nerve or some other vibrating body is subject to movement; or if a vibrating sound proceeds from the throat of some animal, or arises in some other way, then the source of the undulation sets the particles in movement, so that they end in a certain pressure. This pressure, acting on some membrane that is suited for receiving the vibration, immediately causes the membrane to vibrate in a manner corresponding to the undulation in the source itself. It is in this way that the undulation of the membrane in the ear gives rise to an undulation in the nerves, this being communicated by means of the enclosed mechanism.

The same kind of undulation and pressure may be observed in particles of the ninth kind as in particles of the sixth and seventh kinds with no other difference than that the vibratory motion is slower, because the particles are heavier.

155. The greater the pressure exerted on particles of the ninth kind the greater the difficulty of vibrating.

The more particles are pressed, the less do they become, and, consequently, the denser is their volume; hence, the heavier each particle is and, consequently, the less adapted to motion, the slower is the motion, and, consequently, the pressure is greater and more effective. Also the volume becomes denser and the undulation consists of greater volumes. But because the undulatory motion is slower as a result of weight, therefore, such sound is perceived in the organs of hearing as a lower pitch.

156. The particles of the ninth kind possess considerable elasticity, and also aptitude for vibration.

That particles of the ninth kind possess elasticity is clear from this, that they enclose matter of the fourth kind, which is very sensitive to external pressure and expands and contracts accordingly. Hence, as soon as a particle of the ninth kind comes under

the impact of another particle, the surface yields; and it does so, because the enclosed matter gives way. I do not think there is a more elastic particle, for no other particle has matter of so yielding a quality. Consequently, there is the greatest amount of reaction in particles of the ninth kind. That there is also vibration follows as a matter of course, for when a yielding surface suffers impact it immediately recovers itself and then an undulation arises in the surface which is communicated to the enclosed matter. But the nature of vibration in elementary particles will be better seen in the following paragraph.

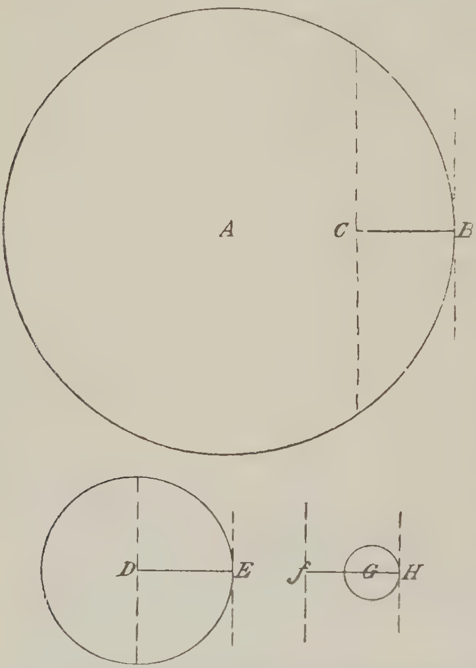
157. A SMALL VIBRATION IN PARTICLES OF THE NINTH KIND SETS UP A CERTAIN BUT MINUTE VIBRATION IN PARTICLES OF THE SIXTH AND SEVENTH KINDS, ALSO A CONSIDERABLE VIBRATION IN PARTICLES OF THE THIRD AND FOURTH KINDS, AND THE CONTRARY.

The diameters and dimensions of particles of the ninth, sixth, seventh, third or fourth kinds, differ very considerably. Consequently a particle of the fourth kind may be said to be very small compared with a particle of the ninth kind. Whence, since a particle of the ninth kind must be considered as a definite mass in comparison with a particle of the fourth kind, it necessarily results that when the larger particle or that of the ninth kind vibrates, that is, when its surface is set vibrating, it will undulate less than a particle of the seventh kind, and a particle of the fourth kind will undulate most, or be moved from place to place.

For an undulation is a reciprocal motion of the particle together with its own centre, while a vibration is the motion of the surface without the motion of the centre. So the more the centre is moved the greater is the undulation. Hence when a small particle is moved, although it is not moved more than a larger particle, still the motion is greater in the small than in the large particle. As for example, if, in fig. 96, *A* were a particle of the ninth kind, although in comparison with a particle of the seventh and fourth kinds it is of considerable size, still,

if the surface were in a state of vibration, so that the movement is from B to C, if, in the return movement, it touched the particle

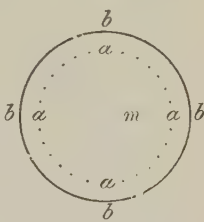
Fig. 96.



D, then the latter would move from D to E, that is, to the distance of the semidiameter of that particle. But if by the same impact G were moved, then this would be moved from f to H, so that it would describe a double path, or the length of its own diameter, consequently the undulation in the small particle G is considerable, when there is any vibration in the larger particle A. Still it is not yet clear to me whether the vibration in a hollow sphere is the same as in these elementary particles, or whether the whole surface undergoes contraction at the same time, or only part of it. It is indeed true that if a particle vibrates, the enclosed matter suffers compression to the same amount. Hence if the enclosed matter is compressed, and the compression is the same in every direction, then it follows that, as a result of the vibration, there will be a very rapid contraction and expansion of the particle. As for example, if in fig. 97, the sphere be struck at b so that the surface bends inwards to m, then I suppose, that in place of a certain vibration in a part only of the surface, the sphere will vibrate as a whole, that is, the particle will become smaller, that is to say, it will be represented by *aaaa*, and then quickly return to *bbbb*, and so continue its vibration. Suppose the elementary particles to vibrate in

this way, still it follows that vibration in the larger particle will set up undulation in the smaller; for if the vibration be greater than half the semidiameter, the particle itself will certainly yield, and undergo change of place in an undulatory way.

Fig. 97.



When, therefore, such a vibration is set up in the surface, it is also set up in the matter enclosed in the particle of the fourth kind, so that there is a like reciprocation of motion.

On the other hand, when particles of the fourth kind undulate, and such undulation is considerable, then it sets up a certain small undulation in particles of the seventh kind, and the said vibration in particles of the ninth kind, and, on the contrary, as previously stated.

158. Undulatory pressure of particles of the ninth kind is reflected.

Reflection takes place in this undulatory pressure in the same way as in matter of the seventh kind, such reflection striking directly on the ear or its membrane. For particles are almost of the same kind, with the difference only that exists between what is greater and less, between heavier and lighter. But the auditory membrane is such that it does not so distinctly perceive all those degrees and modifications which the eye is capable of in matter of the seventh kind.

159. Refraction also takes place among these particles of the ninth kind, but it can rarely be observed.

Since there is such a similarity among particles, and since difference consists only in dimension, in addition to something which does not cause much difference, it is consequently true that refraction also takes place. But as such objects by which the truth can be explored are rare, therefore we may conclude from similarity that there is refraction in this undulatory pressure; that is to say, sound can be increased or diminished when it passes from one medium into another and be refracted on the way by reason of the particles.

Here also we may rightly treat of the pressure of such particles as takes place in proportion to the altitude, opening and area. The pressure is equal in all directions, laterally, above and below. But because the same things occur in the behaviour of a particle of the tenth kind, or water, therefore we must treat of the mechanical and natural qualities of that particle in our description of it.

160. IF A PARTICLE OF THE NINTH KIND BE SO COMPRESSED THAT THE GREATER PART OF ITS SURFACE IS TRANSFORMED INTO SMALL ENCLOSED PARTICLES, SO THAT THE ENCLOSED MATTER OF THE FOURTH KIND IS FOR THE MOST PART TAKEN POSSESSION OF BY THESE, THEN A NEW PARTICLE WILL COME INTO EXISTENCE, WHICH IS DESIGNATED A PARTICLE OF THE TENTH KIND; THIS IS THE WATER PARTICLE.

Before it can be understood how the particle of the ninth kind can be compressed into a new particle, those things should be read which we have previously set forth concerning the compression of particles of the ninth kind and the method of their compression. For we stated that when these undergo compression, parts of the surface are transformed into new and smaller particles, which pass into the cavity of the particle and there float about among particles of the fourth kind; while the matter which is without expands and, consequently, the enclosed matter, in establishing equilibrium, also undergoes expansion; and then these new particles, or the offspring of the delicate air particle, are set free.

Since these particles of the ninth kind can be so compressed, that the whole enclosed matter of the fourth kind is absorbed by the new particles, hardly any or little of it remaining, it follows, therefore, that there is nothing within which is capable of expanding such a particle, but that it is kept closed, as it were. For matter of the fourth kind is enclosed, which expands the air particle; but when this is absorbed, and is intermingled with new and smaller particles, little of such matter remains, and so little that the surface can no longer be enlarged or expanded

by it. And unless this takes place, a new particle comes into existence which is called a particle of the tenth kind; this is the water particle itself.

The nature of this compression, and how it could exist in the beginning of things, may be gathered from the following. The height of the atmosphere, according to some theories, would seem to be several miles. The atmosphere exercises pressure upon itself, so that the higher particles press upon the lower; consequently, in the lowest region the pressure is very great. But in the beginning of things, as stated, the atmosphere, or particles of the ninth kind, could extend even to the centre of the earth, and consequently had an altitude of from 500 to 600 Swedish miles,[1] equivalent to a semidiameter of the earth. Hence, since the atmosphere exercises a pressure proportionate to the altitude, and since the altitude would be equal to such a number of miles, the compression would be the greatest possible. For if the compression is so great with the altitude of the atmosphere at the present time, what must it have been when the height was 500 or 600 miles? Consequently, the air particle must have undergone such pressure that the whole of the matter of the fourth kind around those new particles, and that enclosed in them, must have been consumed; so that no more would have remained in the neighbourhood of these new particles to expand the adjacent surface. Here, then, you have the origin of such particles, and the history of the primitive state of compression, and of the birth of the particles of the tenth kind, or the water particle.

161. The particles which are enclosed in this particle of the tenth kind are variously expanded by the matter of the fourth kind; and also the nearer they are to the centre, the more are they compressed, and the contrary.

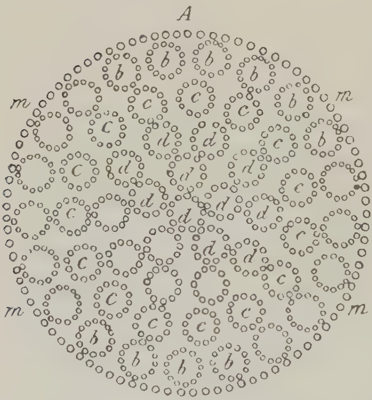
We have already seen what is the origin of the particles of the tenth kind; that is, the surface of the particle of the ninth

[1] A Swedish mile is equal to 11,700 yards.

kind, under compression, betakes itself to the interior, and there, by means of enclosed matter of the fourth kind, is formed into new and smaller particles. Since, therefore, there exists such great compression that almost the whole of the matter of the fourth kind is absorbed by these, then there is nothing to reach within and cause the matter to undergo further expansion. These new particles formed in this way could not be formed in a moment, but gradually and according to the amount of compression. Hence in the first state of compression such newly formed particles are not subject to expansion, nor those which were subsequently produced, whence the diversity of compression in the case of these new particles; and the nearer they are to the centre the more compressed are they.

In fig. 98, let A be a particle of the tenth kind or the water particle; the enclosed particles are those which are formed by the pressure of particles of the ninth kind. When, then, a particle undergoes such pressure, that no more matter of the fourth kind remains, but is absorbed by these new particles—for in them there is enclosed matter of the fourth kind — then it can undergo no further compression and expansion. For residuary particles of the fourth kind are concealed in the interstices of these particles, or between these particles, and since they are few in number, therefore they cannot exercise any force either on these new particles, or on their surface, consequently they are completely dispersed on account of their fewness.

Fig. 98.



When, therefore, the particle of the ninth kind is compressed, then, in the primary state of compression, the surface particles become new particles, as we have previously stated; but the

matter of the fourth kind enclosed in them does not suffer much compression; for the compression of the matter of the fourth kind is almost the same within and without; hence in the first compression particles are formed which are not much compressed.

These new particles, if the suface is moved, place themselves near the surface; for there is a kind of centrifugal tendency in a moving particle of the ninth kind; consequently, these newly-formed particles take up a position near the surface. When the particle of the ninth kind, or the air particle, is subsequently still further compressed, again a part of the surface goes toward the interior, and so passes the nearer particles, which betake themselves nearer to the centre; whence particles of the same kind are formed, but are more compressed; and at the centre the compression is at a maximum.

For example, the particles *bbbbb* are formed in the primary state of compression, consequently they have matter of the fourth kind enclosed within them not very greatly compressed. Still more compressed are *ccccc*, and have enclosed in them matter of the fourth kind still more compressed, while in the particles *ddddd* the compression is greatest, and so the matter seems to be composed of particles of the tenth kind.

From these things it follows that those particles that lie near the surface cannot, of themselves, be broken up, because the matter of the fourth kind, which is still fluent within these particles as a residue, is in a very high state of compression. Hence, when the matter flowing around becomes still more compressed than the enclosed matter, it follows, as a result, that it cannot be broken up. Nor can the surface *mmm* be expanded, for so small an amount of the matter of the fourth kind lies enclosed within as residue, that it can exercise, as it were, no force; and the abundance of such particles gives rise to the possibility of expansion.

Thus you have a description of the particle of the tenth kind. Still one thing remains, that such particles seem to be too large to be formed from particles of the ninth kind, such as are found

to-day in our atmosphere. There is not much difference in magnitude, but there is a great difference in weight. But one may reply to this, that when these particles were created, the particles of the ninth kind seemed to have been larger. For when the vortex of our earth was not far removed from the sun, and in the course of time went further off, these particles of the third or fourth kind, according to our theory, were evidently extremely large; for particles of the fourth kind are larger near the sun than at a distance therefrom. These undergo pressure in proportion to their altitude; hence the nearer the matter of the vortex is to the sun, the more dilated are the particles of the fourth kind. Since, therefore, our vortex was near the sun, before it was carried therefrom to the periphery or circles of the vortex equilibrating with the circumfluent matter, it consequently, would not be wonderful, if at that time the particles of the ninth kind were larger than they are to-day, being now in the circle where the matter of the fourth kind is more compressed. Consequently, the surface matter or that of the eighth kind was in greater abundance, so that such particles of the tenth kind could have been formed, these particles differing not much in magnitude, but greatly in weight. For such particles of the ninth kind were pretty nearly capable of existing in the surface, or in the extreme part of the atmosphere.

162. Particles of the tenth kind cannot be further compressed.

This is clear from what precedes; for there is no more residuary matter of the fourth kind, by whose help new particles could be formed, which would be, as it were, the offspring of particles of the ninth kind. Further, there is no more room for particles of this kind. Hence it follows that they could be no further compressed, except by the greatest possible weight, and in the profoundest depths of the sea. But we shall speak of these in our theory of salts and metals.

163. During this period of the creation of particles the earth would seem to have been nothing but ocean. Subsequently, however, after various changes, dissolutions, movements, and compressions of particles, a definite substratum came into existence, and the waters of the ocean became partially encrusted.

Hitherto it has not been our intention to lay down a theory in regard to the beginning of solids, that is of salts, rocks, earths and metals; for it seemed to us a matter too deep for investigation, a work too great and extensive. It is sufficient to say that all those solids which have ever been found in our earth derived their origin from the fluid particles, whose description has been given in the preceding pages. Nature seems to have brought into existence nothing but fluids and elementary particles. And we have shown that a particle of one kind was created from another up to the particle of the tenth kind. This particle, again, may be broken up by various causes and take on other figures and forms; and as a result a new particle immediately arises, which possesses neither motion nor any elementary quality; and which may, therefore, be designated a solid. A solid particle comes into existence when motion ceases among equal particles. But since elementary particles are spherical, they cannot but move among one another, and by the help of motion all elementary qualities exist and are made evident.

Hence we come naturally to particles of the tenth kind which we stated were produced from compressed particles of the ninth kind near the centre of the earth. Consequently, it follows that this central state consisted of no other matter in the beginning of creation than these particles of the tenth kind; and, consequently, the earth was a kind of ocean, so that in primeval times there was nothing but ocean. But that these particles of the tenth kind subsequently became more solid and also others of which it seems clear that the crust of the earth and the terraqueous globe consisted, must be shown below when we

treat of saline, rocky, and metallic particles, which require an extended and sound theoretical treatment.

164. As a result of their inactivity and of the excessive pressure to which they are subject, particles of the tenth kind may be broken up.

Particles of the tenth kind are held together and their texture is preserved by means of circumfluent matter of the seventh kind, and by the motion of the particles; for since particles of the seventh and fourth kinds flow round and thus exert pressure upon the cavity of the particle, and since there is only a slight pressure within, to which that small quantity of enclosed particles of the fourth kind gives rise, therefore they are bound to be maintained intact. But, in fact, if there is considerable want of movement, so that a kind of stagnation exists between the particles, then they are not subject so equally to pressure in every direction from the matter of the seventh kind, which equality of pressure also arises from the motion of a particle—which has been shown elsewhere—hence particles of the fourth and seventh kinds that are exterior and exert pressure on the convex surface of the particle may be gradually expanded or rarefied between the said particles. Hence that small quantity of enclosed matter of the fourth kind obtains a preponderance, and breaks up the external surface of the particle. Consequently, the new enclosed particles immediately, in turn, slip out; for matter of the fourth kind is able to penetrate between them. But they are forced still further to the outside by particles of the seventh kind; consequently, they cannot so easily pass out, except by means of a certain amount of motion and compression.

We have just shown that as a result of inactivity such particles of the tenth kind may be broken up; also it could be shown that this disruption may result from great pressure such as exists in the deepest parts of the sea. For if the depth of the ocean at the first creation extended to the centre of the earth, there would then have been a pressure exerted equal to that of

five or six hundred miles of ocean, that is, a pressure proportionate to the altitude; consequently, there would be the utmost pressure or weight. When, therefore, particles are subject to very great pressure, I am inclined to think that that structure of a particle which consists of so many enclosed smaller particles, all hollow and not mutually cohering, could not be prevented from being reduced to some other form by pressure, and lose their sphericity.

For if that structure be considered, it seems to be such as to be capable of being disturbed by very great pressure, and reduced to another form. For so many small particles, not cohering very firmly together, and of spherical form, should be capable of being altered by a certain strong pressure. And since the greatest pressure is in a deep sea, it would seem that such a particle must undergo dissolution. But the disruption of such particles and their character must be more fully treated elsewhere.

When, therefore, a particle of the tenth kind is broken up, whether this has been done at the bottom of the deepest sea, or at the surface, when particles are inactive, as it were, those which are enclosed slip out. Those which were nearest to the surface, and also those which were near the centre, may easily undergo dissolution subsequently; especially if they are separated from those in the vicinity. But that break up takes place with a difference. For those which were nearest to the centre, are able to be broken up with the greatest ease, the matter of the fourth kind enclosed in them being very greatly compressed. Hence, when there is greater pressure within than without, it naturally follows that they are very easily broken up, so that I consider that they are disrupted with a certain amount of violence when once dissolution has taken place. But those that lie nearest to the surface are not so easily broken up; for the pressure of the enclosed matter and that without, is almost equal, so that the nexus is not so easily destroyed; and if it does happen, it would seem to take place quietly.

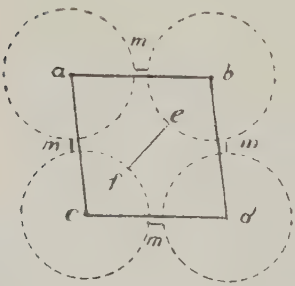
The matter set free, which is that of the eighth kind, can pass in the interstices between the particles, or if much matter of the

fourth kind is circumfluent, and if at the same time there is space, it may become again a new particle of the ninth kind. But of these dissolutions and metamorphoses of particles we must speak elsewhere, when we shall try to deal with the structure and forms of salts and metals. In the meantime we must show, casually, that such particles are capable of being broken up, in order that some little knowledge of these particles may be had.

165. The arrangement of elementary particles, as also that of particles of the tenth kind, is such that one particle is able to pass through the interstice existing between four other particles, above, below, and laterally, and to be the subject of movement intermittently.

Since we have seen that all elementary particles are spherical and extremely mobile, therefore, it is necessary to have a knowledge of the arrangement of such particles—that they are sensitive to movement, and can pass from one place to another: and many other features besides. Therefore there can be no other arrangement among particles than this, that one rests upon four others in a lower position, that one undergoes pressure from four higher ones, and so forth; then one particle can be the subject of motion with all the rest, and one can pass through the interspace between four others, whether this is above, below, or lateral.

Fig. 99.



As to the space which the matter of the fourth and seventh kind occupies, this must be submitted to calculation, and as the calculation would seem to be somewhat tedious, it is sufficient here to adduce the results of a calculation without the details. For example, when the particles are in a position which may be called natural, then the space which the particles occupy in relation to the intervening or interstitial space is almost as

5 to 1; or otherwise, the filled space is to the empty space as 5 to 1. The interval *m* (fig. 99) or the distance between any particle whatever is to the diameter of the particle as 1 to $10\frac{5}{12}$ or as 12 to 125. But *ef*, or the middle distance between the particles, is, according to our calculation, equal to a semi-diameter.

Since particles are so situated, then one moves with all the rest, and one passes through the interstice between others both up and down and laterally.

166. The mobility of these particles of the tenth kind depends on the mobile character of the circumfluent matter of the seventh and fourth kinds.

Between these particles of the tenth kind, matter of the seventh and fourth kinds flows intermittently. And because this kind of particles is endowed with the greatest mobility, therefore particles of the tenth kind owe their mobility to them. For they are incapable of mobility by themselves, since they are heavy, and possess a surface which is unyielding, so that they cannot be compressed, but remain constant in their dimensions. Hence, since they are heavy, and especially are incapable of being compressed and, consequently, of yielding to any pressure applied to them, like the particles of the ninth, seventh, sixth and third kinds, therefore they cannot be mobile of themselves, but they possess mobility from the circumfluent matter of the fourth and seventh kinds.

From these things the reason for the difference of motion in particles of the ninth and tenth kinds can be seen. The former possess a surface having the following characteristics:—it has elasticity; action and reaction are equal and opposite; it can take up vibrations, and also a kind of very rapid undulation. But the latter, because the surface is unyielding, are incapable of vibrating, non-reactive and inelastic; as a result of this there is a great difference between their respective motions. And whatever motion they do possess, must be due to the circumfluent particles of the seventh and fourth kind. Also the

greater the motion in these particles the greater the motion in the particles of the tenth kind.

167. The particles in this position exercise pressure proportionate to the altitude.

This proposition does not stand in need of much proof; because spherical particles exercise pressure in proportion to the altitude. Every particle possesses, as it were, its own freedom. It is unfettered by neighbouring particles, it does not cohere with another except at a single least point of contact; it can move of itself, nor does it cohere with any neighbouring particle; hence also the weight of a particle in a higher position is communicated through the points of contact with particles below it. For if one particle rests upon four lower particles, then the weight of one is distributed over four lower particles, which together constitute a single weight; and so these five particles rest on a lower one with two portions of weight, and, consequently, in proportion to each altitude. But if the form of the particles were not spherical, provided they were equal, a definite pressure would be possible in proportion to the altitude, but not an equal pressure in all directions laterally.

168. These particles at every altitude, exercise pressure equally and laterally in every direction, both above and below; and, indeed, in proportion to the height from the surface.

This can be fully proved when the particles are spherical; but if they had any other form whatever, whether cylindrical or sinuous or eccentric, then the equality of this pressure could not be in any way proved; there would be the greatest inequality in the pressure, which could be proved neither geometrically nor by any other way, nor could it be established theoretically. Hence it can be very clearly shown that the form of the elementary particles is spherical, and that their arrangement is most exact; for one particle exerts pressure upon four lower ones; and these again press upon four laterally; while the pressure of the

lateral ones touches the higher ones also. Thus the pressure in such an arrangement of the particles extends to the higher parts, so that there is no pressure, however great it may be, which is not communicated with the lateral particles, and these with those above, and in every direction. The arrangement of these particles might be made evident to the eye, and the continuity of the pressure, and its transmission in all directions be seen therefrom; but this must be dealt with in treating of particular questions.

169. THE PRESSURE EXERTED BY PARTICLES IS PROPORTIONATE TO THE BASE AND ALTITUDE WHATEVER THE BASE MAY BE, WHETHER LARGE OR SMALL; AND WHATEVER MAY BE THE NUMBER OF THE SUPERINCUMBENT PARTICLES.

This follows from the two preceding paragraphs; for if particles exercise pressure in proportion to the altitude, and if the resulting pressure is equal in all directions, then it follows that the altitude is the cause of the pressure; and that pressure distributed to the lateral particles is exerted among the lower particles, and indeed proportionate to the base. But these points will be dealt with in treating of special subjects.

170. IF AN ABUNDANCE OF MATTER OF THE FOURTH AND SEVENTH KIND FLOWS BETWEEN THE PARTICLES UNDER CONSIDERATION, OR THOSE OF THE TENTH KIND, THEN THEY WILL BE AGAIN EXPANDED INTO SMALL SPHERES, OR A NEW PARTICLE, WHICH IS DESIGNATED A PARTICLE OF THE ELEVENTH KIND, OR THE VAPOUR PARTICLE. THIS ENCLOSES MATTER OF THE SEVENTH AND FOURTH KIND, AND HAS AIR EXTERNALLY.

At length we come to a particle which we can see with the naked eye. The others of which we have treated are beyond the reach of our sight. The truth of our theory can be seen from those things which we discern with the eye. These particles of the eleventh kind are spherical; they can be seen with the eye when an evaporating surface is looked at obliquely.

One may see in this vapour, or in the particle of the eleventh kind, a surface consisting of water; a kind of cavity can be discerned within, which consists of more attenuated matter, expanded by fire or the motion of particles of the fourth and seventh kind. But outside is air or a volume of particles of the ninth kind; so that it may with probability be deduced therefrom that water can form a kind of surface and become spherical when under pressure interiorly from matter more attenuated than that which is without; and that these two kinds of matter exercise a kind of equilibrium of pressure. But because the enclosed matter is lighter than that which is outside, therefore, on account of this lightness among particles of the ninth kind it is raised up to a certain altitude, and indeed to that region where the lightness of the particles of air floating outside equals the lightness of the vapour. We must understand that lightness of a volume of air particles equalling the vapour particle is equal to the lightness of the vapour. Then in this it is dissolved and indeed passes into rain, and thus a drop or small volume of water comes into existence which may be designated a particle of the twelfth kind.

171. Vapour, or a particle of the eleventh kind, may undergo contraction or expansion, and its surface become either denser or more attenuated.

Enclosed matter of the seventh and fourth kinds is that which may be very greatly contracted and expanded, hence, too, when the opportunity is given, this vapour particle of the eleventh kind may undergo expansion and contraction. For provided the same matter which flows around is expanded, or the circumfluent air is expanded, then also the vapour is proportionately expanded through the expansion of the enclosed matter; whence, too, the greater the heat the more the amount of vapour.

So, also, when vapour enters the higher region of the air, where the pressure is less, because the altitude is less, it is immediately expanded by reason of the decrease of pressure, and when it comes still higher, it undergoes still greater expansion

until the surface water is no longer sufficient, and it is bound to be entirely dissipated. Vapour, then, by a certain expansion, would seem to be broken up or dissolved into rain or water drops, which may be called particles of the twelfth kind. But if the surface water of the vapour particle were not lacking, it would be carried still higher before it was broken up.

Similarly, if the vapour underwent compression, then it might be compressed almost to the same amount as the air. And perhaps by compression it might become a large particle, but equal to water, so that some small amount of vapour might float about within the whole of its cavity.

It, consequently, follows that if there were a volume of vapour, it also would exercise pressure, and be subject to pressure in proportion to the altitude equally in all directions, and in proportion to the base of the column; that it would be subject to undulation, and be, in its character, almost like the air, with the difference between greater and less. This also is the reason that it is able to maintain itself so long in air, and to move about with the air; that the air in no way disturbs it, although impregnated with abundance of vapours; that there is a certain affinity between these particles; and that the atmosphere is, as it were, married to the water, but expanded into vapours.

172. A VOLUME OF PARTICLES OF THE ELEVENTH KIND, OR VAPOUR, HAS THE MAXIMUM OF EXPANSION.

I do not think any element or volume of particles has so great a force of expansion as a volume consisting of vapours. The reason is that matter of the seventh and fourth kinds is enclosed, and the surface consists of water particles which have been increased in number there, so that there is not only a simple order or series of water particles, but a multiplication of them; the water particle, therefore, flows in the surface itself as if in its own natural place. But its altitude is a question of the density of the surface itself. Since, therefore, the surface of the vapour particle consists of so great a series of water

particles, it follows that it can undergo expansion only so far as the water surface allows it. For if the series of water particles were doubled, that is, if the altitude of the particles of water in the surface consisted of ten small spheres, then it could be greatly expanded, and yet the simple order of the particles would remain. If it were subsequently expanded, disruption would take place. Moreover, the particles of vapour, or those of the eleventh kind, may undergo still greater expansion ; for if they constituted one volume, so that they were mutually in contact, then if one particle or one vapour particle were disrupted, its surface matter would lapse into the surfaces of lower particles, and so increase their surface matter, that they could be still further expanded. For if there were a volume of vapours, such that expansion could not extend to more than three parts of any diameter, and if some part of the vapour were disrupted, then the matter or the water of the disrupted particles would betake themselves to the surfaces of the rest, consequently, new matter would accrue, by whose help they would be more fully expanded, and the volume itself enlarged. Thus it would regain force from the destruction of neighbouring particles.

If there is some water in the bottom of a vessel, and a volume of vapour above, then fresh matter or water is continually supplied to the particles of vapour, so that they are capable of expanding more and more. And water is added to the neighbouring vapour, which through points of contact rises to the surfaces of the vapours above, and thus gives rise to an equality of expansion. Consequently, we think that in no other particles is there so great a force of distension as in those of vapours. For they are always capable of expansion, and fresh matter is constantly flowing into their surfaces, so that there is nothing to prevent a volume of such particles from having the power to raise the greatest possible weight ; and it is plain from experiments that a solid mass of fused metal can be projected to a height of ten or twelve ells.

173. THERE IS ANOTHER KIND OF SPHERICAL PARTICLE WHICH HAS NO POWER OF EXPANSION.

This kind of spherical particle does not need to be designated by any name; for such particles can arise not only from water, but also from many other fluids. Water takes the form of such spherical particles when much scattered in different directions, and if it is slowly agitated, for then the air attracts the surface of the water, and clothes, as it were, a certain volume with an aqueous surface. The difference then consists in this, that in such a spherical particle air is enclosed, and is also on the outside. The reason why such a particle has no power of expansion is that air is both within and without; and, consequently, the interior matter is in equilibrium with the exterior matter; for neither the matter nor the air that is within could undergo expansion, unless the exterior collapsed. And when the matter within is the same as that which is without there can be no such action or reaction, as in the case of those particles of which we have treated.

174. THE VOLUME OF ELEMENTARY PARTICLES ENDEAVOURS TO ACT UPON CERTAIN SMALL SPHERES WHATEVER THE PARTICLES, ALTHOUGH THEY MAY BE IRREGULAR IN FORM, PROVIDED THEY ARE SEPARATED AND RETAIN THEIR FLUENCY.

The elements which have been described, and the volumes of their particles, always desire to copy their own nature when occasion and opportunity are given; hence it is clear, that when particles are separated by fire, as in the case of rocky, vitreous, saline, metallic, earthy, and other substances, they immediately strive to become vapour and spherical particles; this one can see when fire acts upon fluid mercury. The mercury quickly assumes the vaporous state. The same is the case when particles of lead are acted upon by fire; they are at once dissipated, becoming so light that they are lighter than air, and thus are propelled into the air as if endowed with wings. If water were

mixed with some fatty or soapy matter it would be turned into such a number of bubbles that the whole volume of water would become a volume of bubbles. There are many other points which must be dealt with when treating on special questions.

Appendix on Fire.

In our principles we have not yet dealt with the nature of fire and cold; nor have we assigned a reason why fire can exist between these particles, nor shown in what motion of the particles it consists; and how it can act on adjacent particles. This demands a special work and particular treatment, and indeed a whole volume. For fire acts not only on particles of the third, fourth, sixth, and seventh kinds, but also on those of the ninth kind. Consequently, I could not discuss its nature before the character of all natural particles had been dealt with; it would require an entire work. Hence, indulgent reader, you may expect a treatise from me on fire and cold, in which I hope to be able to place the whole subject clearly before you. But in the meantime I ask your indulgence for the present work, and beg you to give your opinion neither for or against it before you have given it careful consideration, and examined it with unprejudiced mind. I do not indeed say that the theory herein contained is entirely free from error, and I shall be grateful for any correction duly made in a proper spirit.

SOME POINTS BEARING

ON

THE FIRST PRINCIPLES

OF

NATURAL THINGS.

SOME POINTS BEARING ON THE FIRST PRINCIPLES OF NATURAL THINGS.

2. COMPARISON OF THE GENERAL ONTOLOGY AND COSMOLOGY OF CHRISTIAN WOLFF [1] WITH MY FIRST PRINCIPLES OF NATURE. [2]

I WISH to make a comparison between my First Principles and the laws of metaphysics in order to form some kind of judgment as to the foundations upon which our philosophy and theory rest, whether they are based on those things that are geometrically and metaphysically true or not. This cannot be otherwise or better done than by an appeal to the laws and axioms of cosmology of such a learned man as Christian Wolff. It may be said that he is truly a philosopher, and that he has exhausted the principles of true philosophy by continuous study, research, and cultivation; and that he lays down these principles metaphysically, in agreement with law, scientifically and at the same time experimentally. Let us see, therefore, whether there is agreement or disagreement. In his *Natural Philosophy* he discourses excellently on the method of philosophizing. "Perfect freedom to philosophize," he says, "ought to be granted to those who philosophize in a philosophical way, for thus no danger need be apprehended to religion, virtue, or the state." And again, "Without freedom to philosophize there can be no scientific progress." Further, "In philosophy a place must be granted for philosophical hypotheses since they prepare the way for discovering pure truth." Again, "If any-one philosophizes in a philosophical way, he will have no cause to fall into contradictory opinions."

[1] Christian Wolff was born in 1679 at Breslau. He was professor at Halle. He died in 1754.—*Tr.*

[2] N. 1, which we have omitted, is a transcript from the preface to *The Principia*.—*Tr.*

3. Definition of the natural point.

This natural point is not unlike the mathematical point or the point of Zeno; for it gives rise to the particles or compound entities of nature, or our elementary particles. Moreover, by means of movement it originates lines, areas, and geometrical solids of every kind. If this natural point must be defined,[1] it is absolute motion, or motion by means of infinite motion;[2] it cannot be conceived as composite, nor can it be in any way defined as composite, unless we say that it is simplicity itself, genuine, pure and primary.[3] But because the first offspring of the Infinite is being treated of, we must use negative terms: positive ones, adapted to geometrical purposes, are not suitable for framing its definition, thus we seem to sport with words because they are wanting in the characteristics necessary for expressing things of an infinite kind. There is, nevertheless, in it something analogous to the modes existing in finite things, by means of which one may in imagination conceive some of its attributes; still it cannot be grasped by analogy. It is the ultimate where analogies cease; and where these cease is the infinitely minute; and between the finite and the infinite there is no ratio. No similitude can be produced by means of our

[1] In the margin of the MS. these words occur: "It is the primary natural entity existing from the Infinite by means of motion, and thus it is a medium between the infinite and the finite.—*Editor of Latin Edition.*

[2] The words, "This point . . . infinite," are written between the lines in the place of the following words, which were first written and then crossed out: "Produced directly from the Infinite; it is the offspring of infinite nature; it is the primary entity and seed of finite things; thus it exists as a medium between the Infinite and the finite. It is a simple or most simple entity, in no way composite, finited or limited, unless it may be said to possess only one boundary. It is infinitely small; in comparison with the finite it is nothing or something merely imaginary. It is, therefore, without magnitude, devoid of parts. It has no extension, nor are the aggregations of it without motion, if they give rise to extension. It is indivisible; not endowed with figure, nor does it fill space."—*Editor of Latin Edition.*

[3] In the MS. in this place the following words are crossed out. "For this point is a simple entity. Its form is merely or simply form; its motion is merely or simply motion; it is that to which ultimately finite things have reference; it is thus the one end and first limit of finite things."—*Editor of Latin Edition.*

notions and ideas. But lest imagination should be incapable of giving a definition, analogy must be used.

4. The attributes of the point continued.

The question is whether by any kind of philosophical reasoning it can be determined that the point is the medium between the finite and the infinite, or a primary and most simple entity produced from the infinite, and giving rise to the finite, which may be said to participate of both in this way. We say that such is the nature of the point, although we may seem even to play with words.

I have said that it can be understood by analogy; that to this point pertain motion and the form of motion, and consequently form, and also position, and consequently space, but analogically, imaginarily and hypothetically. The motion, however, is not such as is in composites, finites, and things geometrical; but it is simple, infinite, and absolute motion; so also in our conception the motion, compared with finite motion and the quantitative and qualitative characteristics of geometrical motion, has no form; this follows necessarily from the connection of our principles. The reason is that the finite originates entirely from the infinite; finite motion from infinite motion; the extended from the non-extended; bounded figure from the non-bounded; finite space from the infinitely small; the infinitely small from the Infinite, thus the cosmos from the Deity.

Since we cannot reason about the Infinite by anything which corresponds to it, unless use be made of those things that can be ascribed to it by way of eminence; and this because they are not repugnant to it although they cannot properly be ascribed to it, therefore we are bound to conclude that serially there is a medium between the Infinite and the finite; because, to speak strictly, it can be said neither to be finite nor infinite, but rather undifferentiated, for between this and the infinite and the finite there can be said to be no ratio.

I say that before we proceed to the principles of finite things

we must determine what this simple is, for it still has reference to the finite, and this simple to the Infinite.

The matter may, therefore, be put in this way. How can composite, geometrical and finite motion be conceived, unless first a conception be formed of a minimal and extremely small motion from which it originates? how can a minimal or extremely small motion be conceived, which, on this account, can have no perceptible relation to composite and finite motion, unless first a conception be formed of a purely absolute and simple motion, which can be termed nothing but motion? how can geometrical, composite, bounded or finite form be conceived, unless we go back still farther in imagination, so as to have a conception of form in its minutest possible limits? and how can this minimal be conceived, unless a conception be had of simple and absolutely pure form, which is nothing but form? This, we say, is the medium between the Infinite and the finite, this is our natural, or mathematical point. We reason, then, as follows:—Whence are motion and geometrical or composite form unless from the less composite; whence motion and form less composite, unless from a minimal? whence this minimal unless from simple and absolute motion and form? whence this simple and pure unless from the Infinite? whence the Infinite unless from itself? What is Infinite from itself except God and the Deity, the origin and *ens* of all things?

5. The motion and form of motion of this point.

As we have said that this point originates from the Infinite, and thus is a simple entity, and the primary seed of finite things, and by eminence, something which exists, because it was born of the Infinite, and gave birth, as it were, to the finite, we now argue in this way. How could such a point be said to exist *per eminentiam*? We ought to be able to present some little idea of its origin and production, not geometrically, but analogically by comparison with finite things; otherwise we can have no idea of it. If the point existed from the Infinite, it could exist only by means of motion. The sole means by

which it could exist is motion; no other can be conceived. The point then is nothing but motion; simple and infinite motion; and simple and infinite motion is nothing but the point. Its origin can be no otherwise thought of.

Analogically we may reason in this way: Something can exist by means of motion; which otherwise would have no existence. Also, motion exhibits a definite entity quite different from itself; and this can give rise to a form, new, as it were, and totally different from itself.

Let us imagine some small corpuscle, or aggregate of small parts, to move very rapidly, either in a circle or otherwise. This motion will give rise immediately to a figure or form different from the original one. A very rapid motion proceeding from one point to another will give rise to a line; the lateral movement of the line describes an area; and the motion of the area from one position to a lower marks out a solid, although merely the very rapid and reciprocal fluxion of a corpuscle, line or area is involved. So, too, if the same corpuscle revolves round a centre with a very rapid circular motion, a circle will be described; if a semicircular line moves round an axis, a complete surface will be represented; and so on, as is well known. A corpuscle thus moving can represent form by its velocity and direction, or something which previously had no existence, and which is quite different from the corpuscle itelf; and it is in every way a figure so far as our senses and touch are concerned, although it is merely motion which produces the effect; or form is fixed by means of motion.

Let us return now to the point which goes forth directly from the Infinite. How can this be otherwise conceived than as mediant, infinite, and most perfect motion; and this is identical with the point. But I speak analogically.

Secondly, we enquire what is infinite, and, therefore, most perfect motion, by means of which such a point could originate from the Infinite. Again we must speak by analogy, lest the imagination be destitute of some idea of it. Let this motion, then, proceed from the Infinite, for motion from the Infinite

must be infinite, and if infinite, absolutely perfect; and if perfect according to our idea of finite things, its form must be perfectly circular. How could motion be perfectly circular in every way with respect to every sense and all dimensions, unless it were infinitely circular; how could there be motion dimensionally and infinitely circular unless it were perfectly spiral; what could be perfectly spiral unless it were wholly and dimensionally infinitely spiral; and what could be in every way dimensionally and infinitely spiral except this point? But because the motion is simple, infinite, and perfect, the idea that the form of the motion is thus definite and spiral seems to be somewhat opposed to this; for this term implies form, space, composite motion, and something finite and geometrical. And further, this motion is infinite, perfect, and perfectly spiral—there are other infinite and perfect attributes in addition to these—whence it follows that it has not the form of a finite spiral, which runs backwards and forwards from the centre to the periphery. In this case no centre or periphery can be geometrically conceived, nor is there any space into which it can run out; therefore, in defining the form of this motion we must again play sport with words; that is to say, it is not a case of back and forth movement from centre to periphery; but from centres to peripheries, and from peripheries to centres; because there are infinite centres and infinite peripheries; for where there is a centre, there, too, is a periphery, and contrariwise, and in an instant [the point] is in the centres and in the peripheries, or everywhere at the same moment, so that in this case the centre and the periphery are one and the same. The motion cannot, therefore, be said to be either internal or external, unless this is understood undifferentially. There is no mutation of place.

But perhaps the reader will wonder why I make use of words remote from the idea of finite things, words foreign to the common notion, and contrary to the conception of infinite vortical motion or to the form of motion in the point, or in this simple entity, when by such expressions I seem to make sport of our senses. But put away the idea of the finite, conceive of

motion infinitely perfect, imagine it to be infinite, and absolute motion, and the form to be absolute form, the place to be infinitely small, and many other things which we must conceive in imagination before we can arrive at the origin of finite things, and this cannot be expressed except by using phrases remote from the common idea and from the laws of finite things.

But I am able to give a better idea of the first and second particles which, originating from the spiral or vortical motion of points, flow continuously from the centre to the peripheries and from the peripheries to the centre. For if the motion is infinitely rapid it is in a moment in the periphery and in the centre and contrariwise, and so forth.

6. The geometry of the point.

Since, then, this point is not finite and does not possess limits, but is simple, something pure and absolute, or the primary limit or boundary of finite things, therefore geometry cannot claim much footing here. Geometry is concerned with the finite and deals only with bounds and limits or the variations and modes of limits. Still geometry has a certain place here; for here it sees its own beginning, its origin and conception, the little ovum and seed of its existence, and its own limit resulting from absolute motion produced from the Infinite, and also it will see another limit, but at first very minute by means also of motion and the fluxion of the points. Still geometry cannot give any demonstrations here; for it here acknowledges that it is not yet finite, or separate, infantile, or anything. Still we speak geometrically in the fact that geometry has a point as its beginning, which is designated the mathematical point, or the point of Zeno. It acknowledges that there is nothing finite in it, and that in regard to finite quantities and qualities it is equal to nothing. There are many other matters which may be stated in the same way. Therefore, geometry seems to have some right here; but it has to be pursued rather by the imagination than demonstrated.

7. The metaphysics of the point.

Since, then, such a point can receive no geometrical demonstration, we must have resort to the principles and axioms of metaphysics, and in place of the point we must speak of an entity, and thus by means of the attributes of the entity proceed to its investigation.

Now if we considered the attributes of a simple entity, it would be such as possessed only one limit; it would not be bounded or finite, but unbounded and infinite, that from which composite and bounded things proceed; it would be incapable of resolution geometrically, and would not go beyond the bounds of metaphysics. But if such an entity be said to have originated from the Infinite, and to be absolute motion of the Infinite and to be infinite, then also geometry comes in, which would seem to assign definite existence and form to it by means of motion. Therefore both these sciences are concerned with the question, and both grant the point to be of such a character that from it by means of motion, finites can proceed, or, on the other hand, that finites can be at length resolved into it.

8. How subsequent differentiations may take place; in a word, concerning the point.

Let us hasten now to those things which pertain to geometry, first to particles extremely minute and indefinitely small, then to finite and geometrical particles, and by a definite connection to those a volume of which constitutes an element, in which we have ocular proof and evidence of its existence, movement, and form. But it is especially important to proceed in order, both generally as to the series of the particles themselves, and particularly as to the origin, motion, and form of each particle. Hence, in order that an idea may be formed more distinctly of each particle in particular, and of all in general, I propose in the following paragraphs, primarily to give a definition of each particle, then to treat of its motion, form, and other matters which would seem to conduce to a better and clearer understanding of it;

lastly, in the primary division to speak of the origin and cause of such a particle. Secondarily, I propose to treat of its geometry, that is to say, to consider whether it is geometrically true, which I have laboured to do above; also how the attributes of the particle agree with the principles of metaphysics. Thirdly, an effort must be made to show how the same is experimentally and physically true, or how geometry agrees with physics, principles with experiment, what is prior and antecedent with what is posterior and sequent, and whether theory is proved by practice. In each paragraph or treatment of a particle it must in the fourth place be seen whether there is a connection of principles from the primary origin up to that particle which I had dealt with in the previous paragraph.

For unless there is a connection from one end to the other; and unless there is a mutual relation of all the parts, and a continuous and constant thread of principles from first to last, and such a tension, that a touch in one extremity is equivalent to a touch in the other, or an orderly sequence through mediates, and capable of comprehension, the principles could by no means be said to be conformable to nature and the world. For if the thread of principles be broken, there would be as many principles and origins as disruptions; or as many phantoms and dreams as principles.

9. Definition of the first particle.

The first particle is a simple finite entity, a geometrical minimal and bounded; but limited by the least possible boundaries. It possesses very rapid internal motion, than which nothing can be more rapid; it has space which that motion fills, space so small that there can be nothing smaller; it is geometrically the most perfect that can be, that is, the motion of the point is indefinitely rapid; its figure is indefinitely small; the form of the motion is perfect and similar throughout; it is something indefinite and unassignable in comparison with quantities much finited and compounded; it is the medium between the point and finite things, between simples and com-

posites, produced or originating from the points, or rather, from their fluxion into a perfect form, or into a spiral indefinitely manifold, and from a centre to a periphery and flowing reciprocally with incalculable rapidity. It is the first substantial. There is nothing substantial in the world but this finite. No composite substantial can exist except by motion, nor can anything originate except by the modification of something more simple. Motion does not previously determine a substantial, but it is created by motion.

10. THE ACTIVE OF INCALCULABLE RAPIDITY ORIGINATING FROM THE POINT; LET THIS BE TREATED AT THE END OF THE SECTION OR THE FOURTH PARTICLE.

I confess that I have omitted in my study a description of the primary active entity arising [1] from the point, equally as the third active particle arises from the first passive, or the fourth from the second. For if anything originated in the same way from the point, which revolved with incalculable rapidity, and by means of an incalculably rapid motion simulated a surface, it would be regarded as something highly active, and, first, like simple entities, or as a point and its active, just as, secondly, it is like the first and third particles. I say I have omitted this in my study, because a description of any entity is contrary to our idea, because it can hardly be defined geometrically, and because the idea of it ought to be formed in a simple, metaphysical and axiomatic way. And to multiply such entities, when one ought to hasten on to the consideration of the series of finites, and to our finite elements, and their particles, I think to be unnecessary.

Meantime no notion of it can be had unless through its resemblance and likeness to finites, and it must be sought from the third and fourth. Nor can a better idea of the point be had than from its analogy and likeness to a first and second entity. Nevertheless I would not undertake to deny that a highly active entity might be able to exist from a point in the same way as a

[1] In the margin of the MS. it is written "concerning the nexus, see 9, 10."

first particle exists from a third, or a second from a fourth; but to describe the action of this would be also to sport with words.

11. The order of the particles.

The first particles originate from the spiral motion of the entities; the second from the spiral motion of the primary particles; the third from the second motion of the primary particle; the fourth from the second motion of the second particle. The fifth, the primary elementary, least and magnetic particle, together with its mode of compression; the sixth, its sphere produced by compression. The seventh, the second elementary or truly magnetic particle, and its state of expansion and compression. From the fourth volume of our *Principles* those things may be adduced which deal with vortical motion, the primary darkening of the sun, and the breaking up of its crust.

12. Nature is like a spider's web.

Nature is not unlike a spider's web, and natural philosophy like the spider itself. For she hangs her web in places where the threads may ensnare and entice anything to the centre. It causes the radii which it weaves to converge to the centre; and at various intervals in the web it links them up and brings them within the circles or polygons, in order that by means of the threads it may have communication with the whole sphere which it occupies. The spider places herself in the centre and keeps her feet on the threads or radii in such a way that she can feel if the smallest thing touches any thread at any distance. In this way, therefore, she snares flies or other insects. If anything falls upon the threads or web, she, lying in the centre as if in ambush, knows instantly where and in what part of the web it is; for she soon runs along that very thread and no other, and seizes what has been caught therein.

Nature, then, is very much like this web. For it consists, as it were, of infinite radii proceeding from a centre, and of infinite circles or polygons, such that nothing can happen in

one which is not instantly known at the centre, and thus spreads throughout much of the web. Thus through contiguity and connection does nature play her part. In this her very essence consists, for she ultimates where there is contiguity or where there is a connection with the centre and all the peripheries. Natural philosophy is not far from the centre of this very nature, with which centre all natural things are associated, or where all the motion of all the peripheries is concentrated. There she can lie, and, whatever happens in the peripheries, [decide] what it is, and perceive and understand whence it comes, and give a reason to nature why phenomena must successively happen from a definite physical necessity at this and not that distance, in this way and not that. In a word, from the centre those infinite peripheries can be surveyed at once by the mind, or the whole world can be taken in at one glance, and not be confined, as hitherto, to its farthest peripheries, and like flies, be entangled more and more in the web by much labour and effort, and become the prey and sport of its own wisdom and philosophy.

SUMMARY

OF

THE PRINCIPIA

OR

THE FIRST PRINCIPLES

OF

NATURAL THINGS.

SUMMARY OF THE PRINCIPIA.[1]

PART I.

CHAPTER I.[2]

THE MEANS LEADING TO A TRUE PHILOSOPHY.

If the mind and the organs of the senses are fittingly associated, that is, if a man is truly rational, he will continually seek after wisdom. 2. It is also an indication that we desire to become wise, when we are eager to understand the causes of things; and equally so, when we are anxious to know the mysteries of things and matters that are not understood. 3. But he who desires to attain an end ought also to desire to acquire the means. The means that lead to true philosophic knowledge are three in particular—experience, geometry, and the power to reason. 4. By philosophy we here mean a knowledge of the mechanism of our world, or of whatever in the world is within the domain of geometry, or whatever can be revealed by experience with the help of geometry and reason. Within the domain of geometry there are three kingdoms, the mineral, vegetable, and animal; and if yet another can be added, it is the elementary. 5. Within the domain of geometry and under the mechanical laws of motion, both the whole mineral kingdom as well as the vegetable kingdom may be placed, and even the animal kingdom in respect to its mechanical organs, muscles, fibres, and membranes, or as to its anatomical, organic, and vegetative functions.

[1] The *Summarium Principiorum Rerum Naturalium*, or the Summary of the Principles of Natural Things, is found in Codex 88 of Swedenborg's MSS. in the Royal Library at Stockholm. It is reproduced in vol. iii., pages 146-167, of the Photolithographs.—*Tr.*

[2] Chapter I., wanting in the above, has been summarised from the Latin of the Principia by the Editor of the Stockholm Latin reprint.—*Tr.*

6. I am entering upon a serious task in desiring to explain elementary nature philosophically, hitherto deeply mysterious, very far removed from the scrutiny of our senses, and deeply hidden from them. 7. By experience we mean all the knowledge of those things which exist in the world, and can be apprehended by the senses, whether they are among the elements, or dealt with in metallurgy and chemistry, botany, or any other of the sciences, provided it can be known by means of the senses how they operate on the sensual plane or act *a posteriori*. 8. The enquiry into the hidden and invisible things of nature need be no longer put off. 9. For there is no need, as some think, of innumerable phenomena in order to gain a knowledge of natural things. 10. In our present state of ignorance we can become wise only by experience. We would particularly refer to the sciences of metallurgy and chemistry. 11. The reason why men can grow wise by experience, deal with objects by a certain method of reasoning, lucidly investigate, and set them forth, is that they possess an extremely subtle, active principle or soul. 12. All perception passes, by means of a nexus or kind of contiguity, from a grosser to a more attenuated medium. 13. We ought to be instructed by the senses; and only by experience which reaches the mind can we gain knowledge and become wise. 14. I have said that man becomes cultured by the exercise of his faculties, and that the very organic media between the senses and the soul are formed by continual cultivation; without such culture and use these organs would be closed, as it were, and a man would, as a result, become similar to a brute. The slowness of man's coming to adolescence contributes in an important and essential manner to the forming and opening of such organs or motions in highly attenuated membranes. 15. But although we become wise only by experience, those are not, therefore, the wisest who are most experienced; and those the wisest who remember most; but I say that they may become wise, and that experience is the means that leads to wisdom. Consequently, he who should retain deeply stored in his memory all the natural experience

of the world, would not on that account be a philosopher, and capable of understanding the causes of things, and of reasoning *a priori*, unless he knew how to treat everything analytically, by geometry and by rational philosophy; and unless he possessed the faculty of reasoning philosophically, which consists in a certain arrangement and form of the organs connected with the rational faculty brought about by continual cultivation and use. Thus may a man first become a philosopher, enter into the causes of things, and then speak from causes by means of experience. So far respecting the first means leading to philosophic wisdom or the knowledge of the mechanical or organic world. Let us now come to the second.

16. The second means leading to wisdom, by which the mysteries of invisible nature may be unlocked or revealed, is geometry and rational philosophy, by which we may estimate what comes by experience, analyse, and digest it, reduce it to laws, rules and analogies, and thus arrive at a third or fourth deduction which was previously unknown. 17. The world itself, elementary, mineral, and vegetable, as well as the animal anatomy, is purely mechanical. Geometry, therefore, accompanies the world from its origin or its first boundary to the last. 18. Since all things in the world, which are the subjects of motion and have their limits, come under the principles of mechanics, it also follows that both the least and the greatest things proceed mechanically; and that the least and the greatest are similarly actuated. It follows from these things, that the animal body is governed by mechanism, and that in the smallest animal there is a mechanism similar to that in a large animal and in the largest. In the least things there is a better and purer mechanism and more conformable to laws than in those that are large and much confounded. 19. Because nature operates in the world in a mechanical manner, and since the phenomena she presents to our senses are subject to her own laws and rules, it follows also, as a result, that nature cannot operate mechanically except by contiguity and connection; so that the mechanism of the world depends on contiguity; without this there would be neither

world nor mechanism. 20. For the mechanism pertaining to the world is natural to men and animals, or is familiar to them by nature without a teacher. 21. But although the world is a mechanism, and consists of finite things that have originated by means of the most varied contingents, and though the world being such may be richly investigated by means of experience and phenomena, it does not, therefore, follow that everything in the world is subject to geometry. The infinite cannot be at all explored by means of geometry, because it exists as a cause previous to geometry. There are many other things which, although they must have originated from the Infinite and together with the world, nevertheless have not yet been discovered by means of geometry and rational philosophy; as for instance, that intellectual principle, which exists in an animal, or the soul, which together with the body constitutes its life. There is a providence in things, infinite in the infinite or that which is provident in the highest degree; and consequently it follows that there is a connection and series of determinents according to which all events by means of causes and the causes of causes are fixed and disposed, as it were, to a certain definite end. 22. Since that intellectual principle in the soul is not the subject of mechanics, but only the mode by which it operates, the question arises, what is that in the soul which is not a mechanism; and what is its veriest rational and its intellectual principle that is not subject to known laws. The rational principle in the soul is, then, the unbroken power of analysing those things which are similarly scientifically inherent in its organs. Let these statements suffice concerning the second means leading to a mechanical knowledge of the hidden things of nature. Let us come now to the third means, or the faculty of reasoning.

23. The third means of arriving at a true philosophy in cosmological matters, and a knowledge of the hidden things of nature, is the faculty of reasoning. The faculty of reasoning correctly, and of reaching the end by the proper means, that is by experience and geometry taken in a wide sense, is characteristic

of the rational man. All do not possess to-day nor can possess a similar faculty of reasoning. 24. But in order that the nature and character of this faculty may be clearly understood, it must be seen that knowledges and experience should be so disposed and harmoniously diffused throughout the organs, that, when some activity or active force is at hand, all those things so disposed in the organs, being of a similar nature to it, may immediately vibrate and run up to meet it, and be, as it were, present in the soul simultaneously; but no others, except in an obscure connection, as it were. This might be illustrated by the case of a hundred strings on a harp all exactly at the same pitch. If one string is sounded all the rest vibrate without being touched, and concur, as it were, in the same sound, and are heard by the ear in concord and sounding at the same time. It follows from what has been stated that we are wise so far as we retain things in the memory. 25. Therefore, if we summon experiment and geometry to our aid, I do not doubt that, under their guidance and direction, we shall arrive at some knowledge of the unseen things of the world.

26. By a true philosopher we mean the man who, by the means that have been mentioned, has been able to divine the real causes and knowledge of those things in the mechanism of the world which are unseen and remote from our senses; and who is afterwards able to reason *a priori* from principles and causes, concerning the world and its phenomena, whether in physics, chemistry, metallurgy, and other subjects that are under the government of mechanism. If at length it were possible to bring elementary nature to the light, as well as that of metals, plants, and animals, what benefit the world would derive therefrom! 27. No one seems to have been able to attain to a true philosophy, but the man who is said to have been in a state of most perfect integrity, that is, he who was fashioned and made according to the whole art, similitude, and unbroken unity of the world, before vice came into existence. For man in a state of perfect integrity was fashioned as a complete philosopher in order that he might the better know how to venerate the Deity,

the source of all things, or that Being who is in all things; since no one can be a complete and highly intelligent philosopher unless he be a devoted follower of the Deity. True philosophy and contempt of the Deity are diametrically opposed. Veneration for the Infinite cannot be sundered from philosophy; for he who thinks himself to be wise, that is, he who thinks he can be wise without a knowledge and veneration of the Deity, unless his wisdom teaches him to acknowledge the Divine and Infinite, is not wise at all. 28. They, therefore, are mere children, and have hardly come to the first borders of true philosophy, who ascribe the origin of all things to nature, to the exclusion of the Infinite; or who confound the Infinite with nature, when yet nature is only an effect or something that has been caused; while the Infinite is its efficient cause. 29. True philosophy does not detract from belief in miracles; but everything is ascribed by it to Divine omnipotence, as, for example, that the world came into existence, and that this took place by contingents and changes. 30. But I will notice only two states of man, first, that in which he was in a most perfect state of integrity, then his perverted and imperfect state, that in which mortals are living to-day. 31. As to his state of perfect integrity, one may conceive that his whole organism then so synchronised in its various parts, that every movement proceeding from his grosser structures was able to arrive with perfect freedom, through an unbroken connection at a most subtle active entity; or there, where there was nothing which could at all offer the least hindrance. 32. In the perverted or imperfect state of man into which we are born to-day, we see that nothing can be investigated without means, nothing can penetrate to this active principle or the soul except by means of continual experiments, by the help of geometry, and by the faculty of reasoning which must be thus acquired by means of both.

33. The wiser a man is, the greater will be his veneration for the Deity, and the deeper his love for Him. Primevally his pleasures found their end entirely in the love of God, a love which completely satisfies and replenishes every sense of

delight. It would seem reasonable, therefore, that the joys of the first man consisted in this, that the end of the joys, which he derived entirely from the contemplation of a world so perfect and delightful, bequeathed to him and his posterity as an inheritance, and from the agreeable perception by means of his senses and organs of the motions existing in all the elements, was the love of the Deity. The highest veneration, and the deepest love cannot possibly exist without the supreme worship of Him. Therefore, the wiser a man is the greater will be his adoration of the Deity. It follows also for the same reason, that God must have infinitely loved such a man, for love is not only reciprocal, and associative, but it also increases in what precedes and becomes less in what follows. 34. The contrary must also be the case in a man who is not in a state of integrity, and in whom the above-mentioned connection has perished; unless the Infinite and only Begotten, therefore, had been made man, in order that He might restore in Himself also, as a man, that connection with the Infinite; and, consequently, by a certain connection with Himself in those who are like Him.

CHAPTER II.

THE FIRST SIMPLE OF THE WORLD.

1. There is a primary entity brought forth by the Infinite. Nothing finite can exist of itself; therefore, it must exist by means of that which is capable of finiting, and which is of itself Infinite. Therefore composite things originate from simples; and simples from the Infinite, and the Infinite from itself, which is the only cause of itself and of all things. All finite things have come into existence successively; for nothing can be at once what it is except the Infinite. 2. Geometry itself acknowledges a certain simple and primary beginning of its existence, which it calls its own, or the mathematical point.

3. The Holy Scriptures also give us information on this subject and teach us that the world was created by God or the Infinite. 4. Rational philosophy avers that nothing can be or exist without a mode. 5. And if the first simple was brought forth from the Infinite by motion, we are bound to suppose that in producing it there was something of Will that it should be produced. 6. The simple is the primary entity existing by motion from the Infinite, and thus, as to its existence, it is, as it were, a medium between the Infinite and the finite. 7. This point is identical with the mathematical point, or the point of Zeno; it is called the natural point. 8. This point is an extremely simple entity, than which there could be nothing of a more simple character; for a simple admits of no degrees. It is in no respect compounded, finited or limited, because it is simple, except that it may be said to have only one boundary or limit. 9. Since it has one limit, it follows that it is the primary entity and seed of finite things. 10. It is a kind of medium between the Infinite and the finite; for it is by means of this point that finite things exist from the Infinite. 11. This point was brought forth from the Infinite directly. 12. This natural point is purely motion in the universal Infinite; and, consequently, it is pure and absolute motion, a motion which cannot be conceived geometrically. 13. This motion presupposes nothing substantial by which it may be said to exist. How, then, are we to conceive of the absolute and pure in motion? I say that it can only be thought of geometrically and rationally as an internal state or effort (*conatus*) toward motion. Thus we have first the motion of each individual particle, then the state of the whole together, which is an internal state; and thus effort. Therefore, in a simple there is motion, internal state and effort. 14. This point cannot be conceived as having extension; it is without parts, and, consequently, indivisible. 15. Neither can it be said to fill space, unless it be space understood as simple. 16. It cannot be said to have form, unless the form be understood as simple. 17. Form thus conceived is absolutely perfect. 18. In respect to quantities or when

geometrically understood, this point is, as it were, nothing; it escapes the imagination. 19. Nothing can be ascribed to this point which is ascribed to a compound, except by way of analogy.

20. In its pure and most perfect motion are contained all those things, as well active as passive, which limit things finite, and by which they are finited throughout all these series. 21. Since this motion is an effort toward motion or pure motion, its form will necessarily be absolutely perfect; if this be so it will necessarily resemble a circular form. If the circular form is absolutely perfect, it must be perpetually circular or a spiral; the motion must be similar to a perpetual spiral; therefore this motion must have its centre in effort, and it must have a periphery. It cannot, therefore, be said that such motion flows from the centre to the periphery unless you choose to say that it is in the centre and periphery at the same instant, and thus instantaneously present in every part of its space. 22. From the mechanism and geometry of internal spiral motion, there is first a kind of axillary motion, then a progressive motion of all the spirals round their poles; and from the axillary and progressive motion, if there is full freedom and not contact, a second or local motion, and indeed a motion into continuous surfaces. 23. Nature, which is a motive force, flows into no other form of motion more freely than the spiral, through which form its whole velocity proceeds with the greatest freedom and facility through this gradation, and to which, in like manner, it appears to have applied all its mechanical energy and power. 24. Motion is the only means by which anything new can be produced. Motion itself, which is merely a quality and mode, and in no way substantial, may yet ultimate in something substantial, or something resembling the substantial, if the substantial is put in motion.

CHAPTER III.

THE FIRST OR SIMPLE FINITE.

1. FROM the points or simples of the preceding paragraph this first simple or first substantial is produced. 2. Nor can any finite arise from points except by means of motion among the points. 3. The cause of motion must be in the simple or point itself, that is, in the essential internal motion and state of the point. 4. This new motion, or motion of the points among one another, and their state, must necessarily resemble pure motion or the internal state which is in the point; in other words, it must be a spiral. 5. The first finite is the primary entity or simple finite resulting from the motion of the points among one another, and is thus the first substantial of all finites. 6. It is also the least substance. 7. There is nothing substantial in the world except this finite. 8. It is geometrical, and limited, but limited by the least or fewest possible boundaries. 9. It occupies space, but is the smallest of finites, or is such that nothing can be smaller. It has form, but form in its minute boundaries. 10. Its form is the most perfect among finite forms. 11. The forms of such finites are exactly similar. 12. This finite came into existence as a result of the motion of the points among one another. 13. The kind of motion among the points which forms this finite is, in a certain respect, similar to that in the point itself. 14. This finite possesses in itself the same active force as the point; so that it is able to finite and produce the succeeding and more compounded finites; that is, it receives from the point the power of finiting the sequents. 15. Thus the first finite possesses an internal motion as well as the point. 16. This simple finite must be formed by a motion among the points. The points ultimately settle into an arrangement conformable to their motion and figure; consequently, the arrangement thus formed in motion derives its similarity from the motion, figure and space of the

points, and also its characteristic and power of thus moving itself still further. 17. This finite in regard to its substance is the first boundary of all finites; with its motion the calculation of velocity begins; and the analogies between finites cannot be reduced to any smaller boundary and measure. 18. In relation to things much finited and compounded it is nothing, as it were; nevertheless, it is something, and a finite entity. 19. It may be concluded *a priori*, that the motion and the situation of the points thence arising is similar to the internal motion and state of the point, or that it is a spiral reciprocating from the centre to the periphery and from the periphery to the centre. 20 If the continual motion is spiral it must be reciprocal, that is from the centre to the periphery and contrariwise. 21. From the motion of the points arises the fixed arrangement of all, consequently, in a finite as a result of motion and position there arise two poles, one opposite to the other; these two poles have the form of cones. Similarly in every finite entity, whose parts are disposed into a spiral figure, there is an equator, ecliptic, meridian, and often perpendicular circles.

22. From the regular disposition of the parts into a spiral figure, there arises a general effort of all toward the same general motion. This effort (*conatus*), if there is nothing extraneous to prevent it, causes a general axillary motion, or revolution of the finite around its polar axis. 23. From the effort of all the parts toward motion there exists a progressive motion of all the parts and spirals, but which is much slower than the general or axillary motion. In this motion there is preserved a similar arrangement of all the parts and the same figure. 24. Therefore all the primitive force in the point and the derivative force in sequents consists in this, that the motion, state, and effort in the point tend to a spiral figure. This motion, state, and effort cause an axillary and also a progressive motion, which at the same time set up a second or local motion in which consists the active power of finiting and compounding the sequents, and of modifying them through a long series, just as we perceive by our senses that the world is modified. 25. The motion of all

the points must be most perfectly similar and regular; so also must be the progressive motion then arising, and also the second motion. [26. These principles, however, cannot be proved by experience until we have come to elementaries.[1]] 27. Without a nexus, similitude and derivation of causes from one to another, nothing natural could be produced.

CHAPTER IV.

THE SECOND FINITE.

2.[2] SINCE in the universe there is a finite of one kind, and all the finites are perfectly identical, this therefore is the only thing that brings forth anything from itself. 3. Neither can it derive its origin from the more simple and only existing finite except by means of motion. 4. Nor can motion be conceived among finite substantials, unless its cause be conceived at the same time; therefore, the cause itself must be in the substantial itself. 5. But the cause cannot be sufficient, or give rise to an effect, unless there is some contingent, which is this, that the series and abundance of these smallest substantials is so great that they are in contact with one another. Therefore we can conceive of only two contingents, either that so great is the abundance of smallest substantials, that one, by contact, presses upon another, from which contingent there exists a new finite; or that the abundance of smallest substantials is not so great that one by contact presses upon another; from which contingent there exists the active of the first finite. 6. This is a second finite entity, which exists from the motion of the simple finites among one another, and is thus the second substantial of all the finites. It came into existence solely by motion. It is motion which distinguishes finites, gives form, makes one thing equal to another, retains it within its

[1] See *Principia*, chapter iii. n. 26. [2] This is the enumeration in the MS.—*Tr.*

limits and so holds it together that it can subsist as one finite entity capable of being separated from another. 7. This finite consists of only simple finites. 8. It is not divisible into anything smaller than the simple finites of which it consists. 9. It is another geometrical entity which is limited, but within very small boundaries; and there is no finite that is smaller, except the first substantial of which it consists. 10. It is endowed with a figure similar to that of the first substantial. 11. Its figure approaches as nearly as possible to the most perfect figure of the finites; but it is not the most perfect. The figures of all are similar, but nevertheless, there may be a certain dissimilitude between them. 12. The internal motion, arrangement, and state of this finite are similar to the internal motion, arrangement, and state of the first substantial. 13. The motion of the whole, or the general axillary motion, also the motion of the parts, or the progressive motion, as also the second motion, if it has freedom, is similar to the common progressive and resulting second motion of the first finite. From this it follows that the position and progression of the centre of gravity in the second finite is similar to the situation and progression of the centre of gravity in the first finite. 14. The velocity of the second finite, in regard to its general progressive and local motion, is less than the velocity of the first finite. 15. The primary ratio of velocity is in the motion of the first finite; the second ratio is in the motion of the second finite; and this finite in regard to substance, the second boundary. 16. In itself and in its own internal state and motion it possesses the same force and quality as the first substantial; so that it is able to set bounds to and produce succeeding and more compound finites; that is to say, it has received from the first substantial all its power of setting bounds to the sequents. Nevertheless, this force by which it is enabled to set bounds is no longer that of the first substantial, but has its own proper and acquired power.

17. In relation to things much bounded and compounded it is small, and as yet scarcely comprehensible geometrically. 18. It cannot be concluded from principles of geometry, but only from reason, that the motion in a point is spiral; but in the motion and arrangement of the sequents both the geometrician and the physicist may see that it is a spiral. In the lever, mechanics sees its potency and force; in the inclined plane its motion; in the perpetual lever, a perpetual potency; in the perpetually inclined plane, perpetual motion; in the spiral figure, which represents both, it sees concentrated all its possibilities and capabilities. If the centre of gravity consists in motion, so that the centre is itself formed by a continuous and perfectly regular motion, then, in this case, we learn from mechanics that such a body already in motion has a tendency to still further motion, which is under the direction of the centre of gravity. If, therefore, this centre of gravity is not the centre of a quiescent body but of some motion, it immediately becomes lively and active or a living force, which, in a quiescent body, is dead and inert.

CHAPTER V.

THE ACTIVE OF THE FIRST FINITE CONSTITUTES THE SUN, BESIDES FORMING THE FIRST ELEMENTARY PARTICLES.

1. This active of the first substantial is only the motion of one substantial running into circles by means of which a surface is formed. 2. The axillary, progressive, and local motion in a simple or point, cannot be investigated in any other way than as an unknown quantity in algebraic analysis by means of what is known; and, consequently, by means of things posterior and geometrical; and from the axillary, progressive, and local motion, as given in the sequents, it may be concluded that there was something similar in their first origin; and that the quality of the motions in the points may be elucidated by a

similar analysis. 3. If in the first substantial the points dispose themselves into a spiral arrangement, it follows by mechanical necessity, that this substantial must have an axillary rotation. 4. It follows also by mechanical necessity that such a substantial is progressively moved in accordance with the arrangement or order of the spirals; that is, there is in it a motion of the parts, or a progressive motion. 5. The centre of gravity is not in the middle of the substantial, but near its middle, and it follows the progressive motion of the parts and figure. The centre of gravity is in the plane of the ecliptic, but not in the plane of the equator; and the progressive motion is according to regular sequence, or according to the ecliptic of its figure. 6. By means of its axillary motion, there is an effort in the whole compound to enter into a second or local motion; and, consequently, this second or local motion is in accordance with the motion of the centre of gravity. Since the centre of gravity has only an axillary rotation together with the compound, but likewise progresses in its plane, or in accordance with the ecliptic, the local motion describes not only a circle, but also a surface. 7. The actives of this kind flow with one and the same velocity, neither less nor greater; and they always describe similar figures and circles, nor can they describe any either less or greater. 8. In this active there is nothing substantial except that only which is circumfluent; nevertheless, a surface may be represented by motion, just as if it consisted of nothing but real substantials. 9. There is no point in the surface of the active which can be truly called substantial except the one where the substantial is itself present. 10. Nevertheless, it is a most perfectly active entity and endowed with a considerable power of acting upon the neighbouring entities. 11. Nowhere in this surface can a point be conceived that is not acting, although at different times. 12. In respect to this active, finites linked in a series or in an aggregate are passive. 13. This surface may, according to the different degrees of velocity, be represented as more and more like a continuous and finite surface. 14. This surface has no real dimensions;

but it may be called an imaginary and pure surface. 15. When present it acts perpetually upon every finite: by its presence it is enabled to act upon the finites and to dispose them to a certain motion, arrangement, and figure. 16. Several actives of this kind are able to flow in one and the same space without collision or conflict. No collision can take place, that is, one could not run up against another which is in advance of it; because the velocity of all is equal, and the circumference described by all of them is equally distant from any given centre. 17. Several may simultaneously adapt themselves to any angle or space, and, taken collectively, they may represent any figure. One periphery may apparently, as it were, cross and cut another: near one surface there may appear innumerable others, as if crossing through that one. 18. Several in one space can rarely be in contact with one another unless they are in too great abundance. 19. If they meet one another, they nevertheless continue the same rotation over a surface. 20. Innumerable actives may occupy an exceedingly large space, as great a one as the solar space, or much greater. 21. They may also flow within an extremely small space, within a surface consisting of finites. 22. Many collectively in one space possess a greater force of acting than a smaller number.

23. This active arises from the same force and cause from which its coeval or coexisting finite arose. 24. The apparent surface of the active is similar to the surface of its coexisting finite. 25. The fact of the active running into circles, is favourable to activity only by enabling it to be everywhere present, and to act everywhere; but its being able to exercise force upon the bodies it meets, arises solely from its velocity and mass. 26. It could exist before its finite, and be the cause of the contingent giving rise to second finites. 27. Therefore, also, the substantial itself, continually running through spiral circles according to its centre of gravity, can go no further than a certain distance from a given centre, or it can always describe the same equal circumference and surface. 28. As to the force acquired by the velocity; this is evident

from the laws of motion. 29. Here again we have formulated our principles although destitute of experience; for the senses have no experience of things so minute. The fact that a body, by internal motion, may be made to pass into another motion, is one to which ocular experience testifies every moment. 30. By way of conclusion we must now briefly speak of the connection between this active and the finite.

The Active of the Point. This is a point driven into motion by its own internal force, and indeed into concentric spiral circles, by means of which a most accurate surface is formed.

CHAPTER VI.

THE FIRST AND MOST UNIVERSAL ELEMENT OF THE WORLD, WHICH CONSTITUTES VORTICES.

1. In the world we have two kind of particles, one most highly active, the other altogether passive. The one is plainly contrary and inimical to the other. But before anything elementary can exist, it is necessary that there should be two principles in the world, the one active and the other passive. They cannot possibly be conceived as so separated, but that they must unite in one body. Since, therefore, one does not cease to act and the other to be acted upon, before each comes into the position suited to its action or inaction, it may be asked what this position or figure of arrangement may be. Wherever, therefore, there exists a small volume of this kind, consisting of actives and passives, there must necessarily result such an arrangement as accords with the nature of each; so that in this arrangement and space each may subsist according to its own proper force and nature. By means of this new figure there is thus a connection of each with the first substantial from which they derived their origin.

2. It may be defined as being the first elementary particle compounded of the second finites and of the actives of the first

finite, possessing a perfectly yielding and highly elastic surface. 3. This elementary particle is compounded of second finites and actives of the first finite. Thus we have a boundary of space, yet not resulting from the actives which form no boundary, but from the volume of the finites which surround them. 4. The second finites constitute the surface, and the actives of the first occupy the internal space. 5. The surface of this elementary particle is held suspended and balanced in the midst by these two forces. A product of this kind cannot be obtained by the analogies of the motion of the antecedents except by means of space, extension, arrangement, and form; all of which are present if there is equilibrium. A surface may be said to be expanded by the actives included in it: a surface, also, in the midst of two forces is in its natural position. 6. The surface is highly yielding and elastic. We, therefore, finally arrive at this conclusion, that there can be no yielding in any surface unless there be within something which is not contiguous, but which, nevertheless, acts and exerts pressure as if it were contiguous. The actives do not resist as if they were contiguous, but act and push in every manner. Nothing can be more elastic than the surface of this elementary particle. Its rebound is equal to the pressure, or it recoils and reacts with the same force with which it is pressed. The sum of the forces before and after collision is the same, or in every collision or impact the sum of the forces is preserved. The surface when liberated from the compressing force is immediately restored. 7. The weight in the surface is imperceptible, for which reason it cannot be said to lose any weight; and in the particle thus expanded either there is no impetus, or an exceedingly small one. 8. Nothing can be conceived as resisting either without or within the surface of this particle, but only as acting. 9. The finites which constitute the surface are connected together in a contiguous series. 10. The force and effort of all the finites in the surface are always the same and perfectly equal.

11. The motion and conversion of one finite in the surface

of an elementary particle is the motion and conversion of another and of all. 12. The change of state in one finite causes a change of state in another, throughout the whole surface of the elementary particle. The change of state in each particle or finite of the surface, proceeds from an external cause and from compression by means of contact. 13. Since these finites are in connection one with another and constitute a surface, they cannot possibly become actives; but they generally remain passive and inert. 14. If the finites of the surface were disengaged from their series or liberated from their connection with their associated and neighbouring finites, they could not become actives and pass into a local motion, but must immediately pass into some series of the proximate surface and join themselves to a few finites of the same kind. 15. Nevertheless, from an elementary particle there may exist many actives, which, together with the enclosed actives, may occupy a larger space. 16. A small volume of finites may present a large volume of elementary particles. 17. This elementary particle, consisting of finites and actives, may be compressed into one still smaller and smaller; and, again, it may undergo expansion from one of a smaller into one of a larger size. 18. In every degree of compression the similarity of the surface is most exactly preserved, notwithstanding that the surface may be larger or smaller. 19. The series of finites passing through the surface, may flow in a simple, double, or triple order, according to the degree of compression they experience from the adjacent finites. 20. In a state of compression the elementary particle begins to form certain polar cones toward the centre. 21. In the greatest degree of compression the elementary particle changes into some new finite. 22. Then it ceases to be elementary. 23. The enclosed actives have a greater power of acting and reacting upon a compressed, than upon an expanded particle. 24. Under too great a compression, the enclosed actives begin to lose their force. 25. In the greatest degree of compression the actives evidently disappear; they attach

themselves to the finites which occupy the surface, and plainly cease to be actives. 26. The elementary particles cannot be destroyed by any degree of compression, but they ultimately become a new finite. 27. In their greatest degree of expansion they may be destroyed and dissolved. 28. They may be dissolved by actives acting on them from without. 29. These finites may become actives. 30. When set free they may pass into the surface of others which are similar, and there continue their motion. 31. In this elementary particle there may be presented all possible kinds of elasticity, but according to the degree of compression. They possess a greater elasticity when they are expanded, and a less when they are compressed. The surface in the greatest degree of expansion is highly yielding; at length in the highest degree of compression it becomes hard and non-elastic and at the same time ceases to be elementary. 32. One elementary particle touches and presses upon another, and by means of this contact a definite continuity of one particle with another is formed. 33. These elementary particles cannot be in contact, except in a manner accordant with their motion, and their figure. 34. These elementary particles cannot touch one another except when arranged in parallel: so that the poles of all are in a parallel position or line, as also all the larger and smaller circles; and they are kept in this parallelism by the mechanism of their figures and by their contact around the poles. 35. Nevertheless, they may be easily displaced from their position; but they immediately return to it as their natural position. 36. Several of these particles, or a volume, when put in motion, cannot be circumfluent except in agreement with the parallelism or arrangement of all. In the motion of the volume there are also axes, which are the axes of its motion. 37. From the motion of the volume of the particles their vortical motion exists, and no other particles can be better adapted to a vortical motion than these, by reason of their figure and elasticity. 38. Upon the exercise of the slightest force they naturally flow into a vortical motion.

39. There can be no other vortical motion among the particles than such as is in accordance with the figure of each particle, and constantly refers itself to some axis of motion or gyration; likewise the vortical motion forms a certain polar axis. The circles of vortical motion among these elementary particles, which are farther from the centre of motion, are more and more bent until they come into a right line with the axis. This happens until the vortical motion ends in a right line, and so quite vanishes in a direction parallel with the axis of the particles. A vortical motion arises from the exercise of a motive force in a given centre, and when this begins from a centre, the greatest motion is nearest to the centre, and the least at the farthest peripheries. The polar axes of each particle are the same as the polar axis of the zodiac, and their equator the same as the zodiac of the solar vortex.

40. Superficial matter, or finites, flowing through a surface may, near the poles, pass into the surface of the neighbouring particle. 41. By this translation of the finites and superficial matter from one surface to another, the surfaces of the particles may be diminished or enlarged; that is to say, they may become smaller or larger, and thus be brought into equilibrium, as to space and weight, with their adjacent particles. 42. The enclosed actives follow their enclosed particle as if in their own natural location, and they are not sensible of the local motion of their particle. The case is the same with the finites which occupy the surface if there is a local motion of the volume. 43. The cause of their compression arises from the action of one upon another, by means of a motion proceeding from some large space occupied by the actives. 44. A compression of the particles may arise also from their mutual pressure. 45. There is in the volume the same elasticity and proportion of elasticity as in each particle. 46. These particles exert pressure according to their altitude in the vortex. 47. These particles also exercise a pressure according to the base or area and the altitude. 48. They exert pressure equally upward and downward according to the altitude. 49. These

elementary particles do not exert pressure so obliquely as air particles. The altitude of the particles is only according to the plane of the equator of each particle, or according to the planes of the zodiac of the solar vortex. 50. This element is the most attenuated, the first and most universal. All spaces, both the greatest and the least in every world, are occupied by this element; and this element is of all others the most perfectly contiguous. In virtue of this element all things in the starry system appear, as it were, present. Whenever they do not appear so, it is in consequence of our being accustomed to measure distances by comparing the angles made by distant objects with those immediately near the eye. It is in virtue of this element, that we can contemplate the remotest stars, as also the planets, by their reflected light. 51. In this elementary particle all that had pre-existed, is latent, such as the point, the first finite, the second finite, and the active of the first finite.

THE FORM AND OTHER CHARACTERISTICS OF THE ABOVE MENTIONED ENTITIES.

1. The particles of a finite or compound are similar to one another in regard to form, arrangement as well as motion, the individual parts of these again are also similar, and so on up to the first point in which lies the primitive force and primary cause of finiting the sequents. 2. The spires nearest the centre have a greater curvature, and those further off a less, both in the polar cones and in the surfaces. And also in the polar cones it is different from what it is in the surfaces, whether it is nearer to or more remote from the centre. 3. A small cavity is left in the middle which on one side, extends farther from the centre than on the other: and the plane of the ecliptic bisects all the superficial spirals midway from their centre. 4. The centre of gravity is situated outside the middle, and is in the plane of the ecliptic. 6. There is an axillary motion of the whole corpuscle; it is most rapid when the particle is most at freedom, less rapid when in a state of compression, and there is no motion in the highest degree of compression.

There is a progression of the parts in sequent order or along the plane of the ecliptic. This motion is greatest in the greatest state of freedom, and least, or none at all, in a state of compression. From an axillary arises a local motion; this local motion is determined by the centre of gravity, and is directed by the progressive motion into the form of a surface.

7. [The local motion by which the surface is described is spiral; in this apparent surface there are poles, it has larger and smaller circles, just as finites have; and, hence, in respect to form, finites, and actives are similar to one another.]

8. The elementary particles in regard to their figure are similar to the finites and actives. In elementary particles the centre of gravity is in the surface, particularly in a state of compression, when the surface is, as it were, convoluted into several folds. Consequently, in every elementary particle there is an axillary motion; there is also a progressive motion, as also a local motion; or a force and tendency to a local motion. The axillary, progressive, and local motion of the elementary particle is the same in its state of expansion as in its state of compression. The elementary particle in a state of expansion tends to describe a larger circle; and in a state of compression to describe a smaller circle. The elementary particles under the least action in their volume, or even spontaneously, desire to flow in a circle. They are then fully disposed and ready for a vortical motion; a mode of motion, which, for the same reason, they perpetually follow. The finites constituting the surface of the elementary particle cannot be connected and conjoined in any other way than at the poles; and in an arrangement perfectly similar as to the centre of gravity of each. 9. There is a mechanical, geometrical, or physical necessity both for the arrangement and motion of the parts and their compounds.

CHAPTER VII.

THE ACTIVES OF THE SECOND AND THIRD FINITES.

1. The primitive force in the point, such as has been explained, cannot but produce derivatives and must raise itself higher and higher when the occasion is presented, and by its multiplication produce other things similar to itself. 2. All the finites that arise from the points have a similar power, both of finiting and of actuating themselves. 3. The active of the second finite is the same as the second finite itself put into a free state. The second finite becomes active, if there is no contact; the internal force of the second finite becomes motory and passes into act if there is no pressure. 4. The active of the second finite consists of particles which are first substantials. 5. The active of the second finite may derive its existence from the same causes as the active of the first. 6. It possesses the same qualities as the active of the first finite. 7. The only difference between the two is that the active of the second finite describes larger circles than the actives of the first; and it does not move with so great a velocity in its peripheries. 8. The active of the second finite can be in the same space as the active of the first finite, if the space is not too confined; but the actives of the first and second finites can more easily meet and encounter one another than pure actives of one kind. 9. With regard to its mass it is stronger than the active of the first finite; but its velocity is weaker. Nevertheless, the active of the second finite has a stronger impetus than the active of the first. The medium itself in which they flow is nothing; hence the action of one upon another is instantaneously felt. 10. Actives of the same kind always flow with the same velocity, and they cannot flow with greater or less. And so between actives of one kind there are no degrees of velocity, but there are between two kinds of actives. 11. Actives of one kind always describe

the same circles and gyrations, and cannot describe greater or smaller ones. 12. These actives do not form their circles or surfaces round one centre, but round various centres; that is, those derived actives run out into surfaces or circles eccentric and not concentric. 13. By means of this eccentricity the apparent surface of the active seems to describe a new and different surface of its own. By the progression of their centre, actives are transferred into every imaginable point of their space. 14. Actives cannot be said to form anything contiguous, or occupy any determinate place. 15. Actives are devoid of all determinate place and arrangement, unless they are enclosed by finites or elementaries. They can, in their enclosed space, nowhere have the relation of upward or downward. In the active space there is no weight. The largest active space has the same weight as the smallest. 16. Actives cannot be said to resist, but to act only. 17. A number of actives does not constitute an element or matter, nor are the actives themselves to be considered as elementary particles. 18. The force of the active space is increased, and becomes the stronger, according to the number of actives. 19. A space filled with actives of the first and second finites acts more strongly than if filled with actives only of one kind. 20. The solar ocean seems to consist of the actives of the first and second finites.

THE ACTIVES OF THE THIRD FINITES.

1. The primitive force in a point continually produces similitudes of itself by the multiplication of itself into itself, whenever occasion offers, and the force can go out into act. 2. The active of the third finite is the same as the third finite in a state of freedom. 3. The third finite is rendered active if there is no contact with similar finites. 4. The velocity of the third active is less than the velocity of the second, and still less than the velocity of the first. In the same way, the circles and surfaces which the active of the third finite describes, are larger than the circles or surfaces of the second

active, and still larger than the circles or surfaces of the active of the first finite. The mass of the substantial of the third active is greater than the mass of the substantial of the second active. 5. The active of the third finite acts both by its mass and velocity: and it is more powerful in its action than the active of the second finite. 6. The actives of the third and second finites may be simultaneously in the same space. 7. The actives of the third and first finite cannot be simultaneously in one and the same space: since, in consequence of the difference between their velocities, circles, and dimensions, the circles and motions of the first active would be thrown into confusion, and either these would be expelled or else the active would evidently be absorbed. 8. By means of the influx of the actives of the first kind, the actives of the third kind may ultimately lose their active force. 9. There are in the world no actives of the third kind: but they are all third finites and compose the surface of the second elementary particles.

CHAPTER VIII.

THE THIRD FINITE.

THE more the kinds of finites, actives, and elementaries that successively arise by means of multiplication, the more enriched, beautiful, and perfect is the world. 1. The third finite is that which, as to its origin, parts, form of parts, arrangement, motion, and so forth, is perfectly similar to its preceding substantials or finites, or to the second finites, the first finite and the point. 2. The third finite consists only of pure second finites. 3. Since this finite is similar to its antecedent finites, and is a third generation from the points, it is of the same quality as its antecedent finites. 4. This finite derives its origin from the first elementary particle in its state of greatest compression and near the large active or solar space. 5. From these finites there may arise again new elementary particles.

CHAPTER IX.

THE SECOND OR MAGNETIC ELEMENT OF THE WORLD.

1. The second elementary particle consists of third finites and the actives of the second and first finites; also the forementioned finites occupy the surface, and the actives the internal space. 2. The second elementary particles as to their origin, form surface and space, are perfectly similar to the first elementaries; they differ only in dimension—for the second elementaries are larger spatially and superficially, because they consist of larger finites and actives. 3. The second elementary particles have the same elasticity as the first. 4. They may be compressed and expanded in the same way as the first. Their centre of gravity is in some part of the surface, and, when in a state of compression, is nearer the interiors than in a state of expansion. Similarly, these elementary particles have an axillary motion, and a tendency to a local motion. The particles that are nearest the sun and have a greater degree of compression tend to a less gyration and circle; those which are more remote from the sun and in a smaller degree of compression tend to describe a greater gyration or circle. In virtue of the great effort exerted by each, and a certain degree of accessory forces from the active and central space, they spontaneously tend to acquire a vortical motion most adapted to them; a motion which, by reason of the action of the sun and the force and effort inherent in each particle, they perpetually preserve. 5. The surface of the second elementary particle is exactly balanced between two forces; interiorly it secures pressure from its own active, and exteriorly by the first elementaries. The first and second elementaries may concordantly flow in one volume, sphere, and vortex. 6. These second elementary particles are similarly subject to the pressure of others resting upon them, and the pressure of the incumbent particles is proportioned to their altitude in the plane of the

zodiac, and also to the area subjected to the pressure; provided their volume be reduced by motion to a regular and vortical position. 7. The third finites constituting the surface of the elementary particle unite and become passive, in a manner similar to that of the second finites in the surface of the first elementary particle. 8. The finites constituting the surface, like the finites of the first elementary, have their convex and lighter part toward their internal space and are thus compelled to cohere with their poles. 9. The motion and essentials of the volume are similar to the motion and essentials of the parts in all the elements reciprocally. 10. The second elementary particles may be compressed into their smallest compass in the same manner and by the same cause as the first elementary particles. In their highest degree of compression, or nearest the large active solar space, they change into new finites, which may be called fourth finites, and are similar to the preceding. 11. In every particle of this elementary kind there is everything in the world which has hitherto arisen from the point; and every elementary particle is a smallest compendium of the world and its preceding entities; there is thus a most perfect harmony between the parts and the compounds, and the closest connection of all with the first.

CHAPTER X.

THE EXISTENCE OF THE SUN AND THE FORMATION OF THE SOLAR VORTEX.

1. THE large active solar space could primitively have consisted only of the first finite. 2. No space or place can be occupied or enclosed by actives, unless it is surrounded by finites in which alone it can be terminated and limited; and, consequently, in respect of which it can be called a space. 3. By the tremendous action of this space the surrounding finites could be reduced into such

an arrangment, that one might be in contact with another, and, consequently, enabled to finite themselves, and, by means of motion among one another, flow into second finites. 4. The second finites now surround and enclose the same solar space; since the first finites, for the forementioned reasons, have coalesced into the second. In the same manner these second finites, which are now next to the solar space, may enter in a considerable number into the space and become actives. 5. Both the first and second elementary particles may now take their rise round this large active space; and may successively form a sphere which gradually grows larger, until at length they suffice to form a certain large vortex round the sun. 6. In the state of the formation of the vortex among the elementary particles as they were growing into an immense sphere or volume, no other force was needed than a certain active centre; otherwise the elementary particles themselves would spontaneously dispose themselves in a general motion conformable to the figure of the parts; and by the action which takes place in the centre, they would perpetually continue this motion both as to each particle and also as to the whole volume. 7. The sphere of the elementary particles flows entirely from the action of the solar space, into a vortical motion; this motion must accord with the equators and poles of the parts, and hence must extend itself into a spiral figure at a considerable distance from the centre; and must, consequently, by the motion and arrangement of its particles, form a zodiac. 8. Elementary nature is similar to herself both in the greatest and least things; in the macrocosm and in the microcosm; in a heaven and in a small volume; in a world and in a particle.

PART II.

CHAPTER I.

THE CAUSES AND MECHANISM OF THE MAGNETIC FORCES.

1. The first elementary particles and also the second, or the magnetic, have the most perfect aptness and susceptibility to motion; and, indeed, they spontaneously make an effort to go into a certain vortical motion, if there be only an active centre around which they can flow and gyrate. 2. In a volume of elementary parts all the motion is diffused and derived from a certain centre, where the origin of the motion exists, to all parts round about; and indeed to a greater or less distance according to the force of the centre, and the contiguity, elasticity and yielding nature of the parts. 3. But the motion among the elementary particles is not only propagated and extended according to the figure and natural arrangement of the parts, but it also terminates in them. 4. Hence it may be concluded that motion among the first elementary particles, and also among the second or magnetic, is diffused in every direction from the centre to all the circumferences. But as the figure and arrangement of the parts is such, that the poles of all the particles, and also the equators of all the particles are parallel, the motion among the particles is diffused in one way according to the poles, and in another according to the equators. 5. Since the diffusion and propagation of motion from the centre is of one kind according to the plane or parallelism of the poles, and of another and different kind according to the plane and parallelism of the equators of the parts, it follows that motion cannot be diffused into circumferences equidistant from the centre, or similarly circular, but only into such as are spiral. A motion of this kind

in a volume of parts is truly vortical. 6. In the spiral or vortical motion, the nearer the spires are to the centre, the greater is their curvature; and the further off they are, the less is their curvature, till it gradually ends in a right line, and then in the arrangement of the elementary particles. Finally, all motion between the elementary particles, which we have called magnetic, runs round a centre in a spiral direction, and when it has arrived at its state of rest, comes into a rectilinear arrangement, and into the same with the arrangement of the parts at rest; in this all magnetism consists, of which we must treat. 7. These spiral gyrations we call vorticles. As many spiral gyrations or vorticles may arise as there are centres of motion, and the vorticles themselves may be conjoined among one another agreeably to their form and motion. 8. If the vorticles are united according to their spirals and the harmony of their motions, they are, as it were, mutually bound together by the union, and tend to remain in it. 9. Vorticles or spiral gyration, of this kind, have a greater tendency to union with one another the nearer they are to the centre, or the greater curvature of the spires where they are conjoined. The closest union of motion is nearest the centre of motion, because there the gyration has the greatest curvature; in the intermediate distance, the degree of union is intermediate; at the farthest distance there is none, inasmuch as the gyratory motion there begins to be determined into a right line. Moreover, union exists wherever the angle of the spiral is less than forty-five degrees. If in the same plane there are several centres of motion, the greater is the gyration and union of the vorticles; the fewer in the same plane, the less the union; also there are as many unions as there are centres of motion.

10. Corpuscles having pores and interstices so minute as to be permeable only by magnetic particles I designate magnetic corpuscles; especially if the pores or interstices are rectilinear. Of this kind are very small corpuscles proceeding from magnets and iron or effluvia. 11. Particles of this kind, or effluvia, when free, cannot be quiescent, but they gyrate continually round

their centre, according to the arrangement of the elementary particles. They constitute, therefore, active centres, and form around themselves spiral gyrations or vorticles. 12. Accordingly, as is the number of magnetic effluvia, such is the number of vorticles formed round the magnet. 13. The greater the quantity of this effluvia round a magnet, the greater is the number of vortices and vorticles; also, the more nearly and closely may they be conjoined and united by their interior spirals, and contrariwise. 14. The natural place of this effluvia is in the centre of this vorticle; nor can the effluvium residing and acting in the centre project itself out of the vorticle; for it is inseparable from the vorticle, and is naturally carried in the direction in which the vorticle moves, and contrariwise. 15. If within any hard or material body there are effluvia, or smallest parts of this kind, both free and associated, but extending in a right line, or in a regular curve, from one side to the other, or from one pole to the other, then, I hold that such a hard or material body is wholly magnetic. 16. The more regular the arrangement of the particles, and the greater their quantity both within and without the mass, the closer is their union and the stronger their magnetism. 17. The union of the effluvia or vorticles is closer at a shorter than at a greater distance from the mass; and closest at its confines or boundaries, or nearest to the mass. 18. The vorticles around this mass, by a continuously connected link, are poured round from one polar wall to another, and thus connect and enclose each wall and pole by means of a definite sphere. The sphere of vorticles thus connected may continue for a considerable time round the whole magnet; nor is there any need for it to be constantly supplied and renewed with fresh effluvia; nor is any great quantity of these continually going forth required; nor can the magnet itself, surrounded with such a sphere of vorticles, be removed from one place to another, without removing the whole sphere with it; nor can the sphere be removed without removing the magnet with it. The magnet and the sphere constitute, as it were, one body; the one

cannot be separated from the other, much less can one be moved away from another; but the magnet always in the centre of its sphere in whatever situation and motion, naturally and always accompanies the sphere, and the sphere its own magnet. 19. By reason of the connection between the vorticles which extend from one pole to another, and of the formation of the sphere, poles exist on both sides of the magnet. There are similarly polar axes extending in the sphere to a distance from the magnet; and these axes do not receive their direction from the magnet itself, but from the sphere and its figure.

20. The axes of the vorticles are not parallel to that of the spheres; but are deflected according to the figure of the sphere, and this deflection begins at the polar axes of the sphere. 21. The axes of the vorticles and the axes of the elementary particles round the magnet are parallel; and the elementary particles are disposed by the motion of the vorticles into the same arrangement, and the same form of arrangement as the sphere. 22. The whole motion in the vorticle is according to the position of its axes; or the axes have a curvature conformable to the motion. If the axes are in a right line, the motions in the vorticle are concentric; if the axes are curved the motions are eccentric; and if several vorticles are in the vicinity of one another, according to whose motion and application the axes are to be curved, then at different distances from the centre or effluvium there are different eccentricities. 23. The axis of the sphere, or the common axis of the vorticles, lies parallel to the common axis of the element itself, so as to be exactly accommodated to it; but, nevertheless, it may be easily directed from this into any other direction. 24. The axis of the whole sphere, or the common axis of the vorticles, may be curved in a similar manner; and together with it, the sphere itself may also undergo any change from one pole to another; or what amounts to the same the sphere itself may from one pole to another undergo a change, and in accordance with it the polar axis will be bent. 25. By the application of two or more magnetic spheres, the

figure of each is immediately changed; and from two or more spheres arises one that is larger; and the whole of the distance between the spheres becomes an axis. According to the different application of the spheres, the larger sphere thence arising is differently formed. 26. Two or more spheres applied to each other are more closely united at a smaller than at a greater distance. 27. The conjunction of spheres is closest and most direct at the poles; but between the poles it is slighter and oblique.

28. The greater part of the effluvia of iron or steel is magnetic; but in consequence of the irregular arrangement of the parts in iron or steel, there is no regular connection between the effluvia or vorticles; consequently no sphere can be formed by such regular arrangement of the parts, nor can any magnetism be produced before the vorticles with their effluvia interiorly in the iron or steel are reduced and disposed into regular arrangement. 29. If the effluvia of the iron approach the effluvia of the magnet, or the sphere of one approaches the sphere of the other, both spheres coalesce and unite into one that is larger, and the whole distance becomes an axis, thus the magnetism is rendered more powerful. For this reason also it follows that iron is conjoined with the magnet, and that the magnet is conjoined with iron, by means of spheres; that one invites and attracts the other, as it were, by a certain force; that they are not repelled in different directions, as one magnet is by the similar or repelling pole of another. It follows also that the iron is conjoined with the magnet to the same extent to which the common sphere either penetrates or surrounds the iron; and that the whole mass of iron is conjoined with the magnet, provided the whole mass be penetrated or regularly surrounded, unless its weight should be greater than the force of attraction exercised by the vorticles or sphere. 30. By the application and contact of the magnet and the iron, we observe that, in the structure of the iron, all the effluvia, which are perfectly or partially free, are disposed into a regular arrangement; and that the iron is thus rendered magnetic.

CHAPTER II.

THE ATTRACTIVE FORCES OF MAGNETS AND THE RATIO OF THE FORCES TO THE DISTANCE.

1. THERE is no magnet absolutely the same as another, either as to its interior structure or as to the form of its surrounding sphere; and the magnetism in the same stone is subject to variations arising from very varied causes. 2. The attractive force or conjunction of two or more magnets or pieces of iron, depends not only upon the axis but upon the whole surrounding sphere. 3. The attractive force between the magnets is strongest at a small distance, weaker at a greater; and none in the place where the spires of the vorticles begin to embrace one another at an angle of 45°. 4. There cannot be two magnets possessing the same attractive force; but in magnets perfectly similar, there is always a constant geometric ratio between the attractive forces and the distances.

CHAPTER III.

THE ATTRACTIVE FORCES OF TWO MAGNETS WHEN THEIR POLES ARE ALTERNATED.

THE magnetic sphere about one pole is not similar to the one about the other pole, nor can the axis at the south be extended in a similar way to that at the north pole; but in the figure of the sphere there is always some difference on each side; consequently, at each pole, there is not always exerted the same force; nor is the attractive force of two magnets the same if the poles are alternated, that is to say, if the magnets are inverted, and homogeneous poles are opposed to each other.

CHAPTER IV.

THE ATTRACTIVE FORCES OF MAGNETS WHEN THEIR AXES ARE PARALLEL.

1. WHEN two or more magnets are so placed that the equinoctial of one lies upon the equinoctial of the other, the spheres of the two magnets combine into one that is larger and form a certain large axis between the poles of the magnets. But the spheres of two or more magnets are, as to the poles, mechanically so conjoined according to the motion of the vorticles, that in the middle distance between the magnets, the vorticles are situated parallel to the axes of the magnets, but at the sides they are perpendicular to the axes; and, consequently, between the middle and extreme distances, they are in a position oblique to the axes. 2. Two or more magnets, placed in a position in which their axes are parallel, or in which they lie in the direction of their equators, possess in like manner a conjunctive force; but yet not at the same distance as when they are conjoined by the mutual application of their axes or poles.

CHAPTER V.

THE REPULSIVE FORCES OF MAGNETS, WHEN OPPOSITE POLES, OR POLES OF THE SAME NAME, ARE APPLIED TO EACH OTHER.

1. IF two or more magnets are so applied that the south pole of one is opposed to the south pole of another, or the north pole of one to the north pole of another; that is, if two poles of the same name are opposed to each other at different distances, then the spheres of each magnet will coalesce into one large sphere. But in the middle distance between the magnets thus applied, the arrangement and motion of the vorticles are nearly contrary to

one another; but at each side they bend themselves toward their natural and homogeneous position. And in the middle of the column thus formed, there is a disjunction of the parts; but at the sides there is a conjunction. 2. If poles of the same name are turned toward each other, then the magnets are partly repelled and partly attracted; and their repulsive force is increased according to the distances and ratio of the spheres, but at a smaller distance is gradually diminished. Two or more magnets opposite one another, outside their perpendicular line, co-operate, if either of the poles be in the least oblique, or if the magnets are removed very slightly out of the diametric line of opposition. 3. Between the distances and repulsive forces of magnets, there cannot be any rule of proportion, unless the magnets, together with their spheres, are absolutely alike. 4. If, therefore, two or more magnets are applied to each other so that the homogeneous or agreeing poles face each other; then, from two or more spheres arises a single large sphere having two poles, one at each end of the magnet and the middle distances between the magnets becomes its axis, equalling the entire side of each magnet. If, however, two or more magnets are so applied that their poles are parallel, but their equators opposite to each other, then from two or more spheres also arises a single larger one, having four poles, two supplied by each magnet. The case, however, is otherwise if inimical poles, or those of the same name, are opposed to each other. From these circumstances, assumed as a basis, we may proceed to ascertain the nature of the coalition of the spheres, or what must be the figure of the larger sphere if more than two magnets are brought together; also what it must be if two or more are placed opposite to each other in some other position more or less oblique from the axes or equator, and at various distances and angles.

CHAPTER VI.

THE ATTRACTIVE FORCES OF THE MAGNET AND IRON.

1. When iron is applied to the magnet or the magnet to iron, then out of two spheres there arises one that is larger, and which encloses both the magnet and the iron, but not in the same way as when one magnet is applied to the other. 2. The reciprocally attractive force of the magnet and the iron is greater than the attractive force of two magnets. 3. The magnet exercises its greatest force upon iron of a given proportion of mass and thickness; the force is less if the iron is too thin or too thick. 4. The magnet exercises its greatest degree of force upon iron of a given proportion of size and thickness,[1] and less if the iron is too small and less also if it is too large.

CHAPTER VII.

THE INFLUENCE OF THE MAGNET UPON HEATED IRON.

The magnet operates with less force upon white hot iron or heated iron than upon cold iron; and its influence upon heated iron decreases according to the degree of heating.

CHAPTER VIII.

THE QUANTITY OF EXHALATIONS FROM THE MAGNET, AND THEIR PENETRATION THROUGH HARD BODIES.

1. The magnetic sphere can flow with the greatest freedom not only through volumes of the elements, such as air and

[1] In the *Principia* at this place the word is *superficiei* (=surface), not as here *crassitiei* (=thickness).—*Trs.*

ether, but also through water and flame; similarly through hard bodies, whether of wood or stone or metal. Nor do the effluvia which penetrate the texture of harder bodies anywhere lodge, impinge against, or become affixed to, any of their parts or surfaces; but flow with perfect freedom throughout the entire mass without contact, collision, or impact. 2. Nor can the magnetic sphere conjoin with itself any other kind of metal except iron and steel, or such as participate in iron. 3. By a larger quantity of outgoing effluvia, the magnetism and power of attraction of bodies are increased. Still, however, there is no need that a wave or tide of effluvia should perpetually pour forth from the magnet; so that the magnetism should be renovated and restored by a continual influx and efflux of effluvia. 4. Iron cannot acquire by friction against a magnet any increase of weight; but the smallest parts of the iron drilled into a straight line, and partly loosened by friction with the magnet, are only turned and brought into a regular arrangement; and thus it is that magnetism is communicated to iron; therefore the magnet experiences no loss of its forces, since one magnet alone would suffice to render magnetic all the iron in the world. 5. He who resolves to form and build up principles by geometrical and mechanical methods and afterwards to confirm them by experiments, must not take up and refute the opinions and arguments of others; but must only present to notice causes, and demonstrate the connection between first principles and experiments.

CHAPTER IX.

CHEMICAL EXPERIMENTS WITH THE MAGNET.

By means of fire or great heat, the magnet is made to lose its force, and also the rectilinear and regular arrangement of its parts, and together with these its magnetism; and, consequently, to assume the nature of iron, and is unable to form around itself

any regular sphere. After being raised to a white heat, nothing remains which enables it to adjoin itself with another magnet, with the exception of its iron parts. 2. By sublimation, solutions, and other chemical operations on the magnet, its parts, and structure, nothing further can be discovered, than that a magnet consists of parts of different kinds, but that the magnetic virtue and quality reside only in the iron particles. 3. By reducing the magnet to dust, the magnetic quality is lost and dispersed. 4. However, by the application of some kinds of salts, the interior parts of the iron, or of the magnet, may possibly become so associated with them that the supply of iron or magnetic effluvia may have no power to go forth, and thus to separate itself, until a melting heat disengages the iron parts from their bonds.

CHAPTER X.

THE FRICTION OF THE MAGNET AGAINST IRON.

THE magnetic parts which are in iron are disposed in a regular arrangement by means of friction; and a magnetic sphere is thus formed round the iron. But iron may be rendered very strongly magnetic and very permanently magnetic, if it is rubbed against the magnet, and thus is in actual contact with it; but less magnetic, if it is not in contact. If it is placed at a distance from the magnet, it is indeed rendered magnetic, so long as it is within the magnetic sphere; but if the sphere be removed, the mechanical order immediately ceases. 2. Iron is rendered very strongly and very permanently magetic, when all its parts or its entire structure, are reduced into the same regular arrangement; and less or least magnetic when the parts of the iron are reduced to this arrangement only in certain points, or throughout a less distance. 3. When the smallest parts in the iron are once reduced by friction into a regular arrangement, they cannot by any further friction be brought into a still more regular order; nor can the

magnetism of the iron be rendered stronger by repetition of the friction. 4. Iron is rendered by friction very strongly magnetic if it has a certain definite mass, thickness, and surface. The size, mass, thickness, and surface, may be determined by experiment; taking into account, however, the nature of the iron and of the magnet.

CHAPTER XI.

THE ATTRACTIVE FORCE OF THE MAGNET ACTING UPON SEVERAL PIECES OF IRON.

1. One magnet is able to attract to itself in order several pieces of iron, and enclose all of them with one and the same sphere. 2. The conjunctive or attractive force of the magnet may increase and be rendered greater by the application of iron, or by an armature. 3. There cannot be two magnets absolutely similar to each other as to their attractive force.

CHAPTER XII.

THE ACTION OF IRON AND THE MAGNET ON THE MARINER'S NEEDLE, AND THE RECIPROCAL ACTION OF ONE NEEDLE UPON ANOTHER.

1. The sphere of the effluvia round iron extends itself to a considerable distance; so that the vorticles or gyrations of the effluvia emanate like radii on every side, and dispose the magnetic element itself into the same arrangement; whence this magnetic element regards the iron as its pole or centre, from which the vorticles issue in a long series.

2. Innumerable spheres, whether pertaining to iron or to a magnet, may be formed within one and the same sphere; and each sphere may act according to the situation and motion of its parts.

3. In every magnet there are qualities and forces of two kinds; one, that of attracting another magnet or a piece of iron, which is called the attractive force; the other, that of accommodating itself to the parallelism of the magnetic element, or to its poles, which is called the polar force or declination of the magnet.

4. Within the sphere of the iron, or at some distance from it, the mariner's needle is turned toward the iron, not by an attractive force, but by its own polar quality.

5. The axis of the sphere, or the common axis of the vorticles, lies most conveniently in a position parallel with the common axis of the element; but it may be easily turned thence toward any other quarter.

CHAPTER XIII.

OTHER METHODS OF RENDERING IRON MAGNETIC.

1. Iron may be rendered magnetic in other ways than by friction and contact. The means effecting this consist merely in bringing the smallest parts that go forth in the form of an emanation into a definite position. If, therefore, iron be exposed to the continual action of the magnetic element for a considerable and stated period, it will be rendered magnetic; particularly if it be placed in a position which coincides with the parallelism of the elementary particles. 2. Iron may also be rendered magnetic by repeatedly stretching and bending it; also by regular filing and hammering it out. Experiments of this kind afford additional evidence in favour of our first principles; namely, that all magnetic force consists entirely in the regular arrangement of the parts, and that all the effluvia from iron are magnetic. From these data follow definitely all that which we have hitherto ventured to maintain concerning the modes and qualities of magnetic forces in the magnet and iron.

PART III.

CHAPTER I.

COMPARISON OF THE STARRY HEAVEN WITH THE MAGNETIC SPHERE.

1. The elements treated of in the first part of our *Principia*, act on a small scale in the same way as on a large one; in a volume, in the same way as in a system; in a vorticle round the magnet, as in a great vortex round the sun. They act in the same way whether the active centre be an insignificant effluvium constantly moving round its axis, or whether it be a large and constantly moving solar centre. In the heaven or finite universe there may be innumerable vortices of this kind, if there be innumerable active centres; or there may be as many vortices as there are suns or stars.

2. The motion of each vortex is from the active or solar centre to the circumferences; but the motion toward the equators of the parts is not similar to the motion toward their poles, by reason of the geometrical difference in the figure of each part. In consequence of this difference of motion, the formation of the spiral gyrations is toward the poles and axes of the parts; that is to say, in the larger system, toward the poles of the zodiac. The spiral gyrations have a greater curvature in proportion to their proximity to the centre of motion, or to the sun or star; and the farther away they are, the less is their curvature. The spiral motion which takes place according to the poles or axes of the parts, is expanded and unfolded into one more and more rectilinear, till at length it terminates in a common or rectilinear or parallel situation of the parts.

3. Two solar or stellar vortices are more closely associated by the spires nearer to the centre than by those more remote, as is evidently the case with the magnetic vorticles; they may be associated either at a great or at a small distance; they may be reciprocally associated if one axis be opposed to another, but not if one equator be opposed to another; that association as to the poles is direct, but association of the poles with the equators of the parts is indirect and oblique. There is no association as to the equators of the parts, that is to say, in the large vortex, as to the zodiac; the centres of motion or the various suns and stars, may thus be at greater or less distances from each other. If there are several in a smaller space or at a smaller distance, the gyration of one is not disturbed by that of the other. To prove this would be only to repeat what we have before stated.

4. The active, solar, or stellar spaces in the middle of the vortex are there in their own natural locality; they cannot be removed out of the vortex; the centre is indivisible and inseparable from the vortex, and the vortex from the centre; one follows the other; and there cannot be two or more suns, stars or active spaces in one vortex.

5. Further, one vortex with its active centre constitutes one heaven of itself, or one mundane system; several vortices with their centres form together a certain sphere. A sphere consisting of many vortices of the same kind has its own proper figure, and the figure of every sphere its own proper axes. The vortices bend their course in every direction from one axis, and curve it toward another; round the other axis they are inflected and bent in like manner, whence by the colligation of the vortices the sphere passes on to another axis. The sphere is so bound up with its axis, that all the vortices in the entire sphere have reference to the axes; so that no vortex can be moved out of its place, unless the figure, connection, order, and course of the whole sphere is in some measure disturbed. Vortices are larger in proportion to their greater distance from the axis, as also in the axis. The whole visible sidereal heaven

is one large sphere; and its suns or stars, together with their vortices, are parts of a sphere, and connected one with another in the manner we have mentioned.

6. The axes of the vortices in such a sphere are variously bent and curved, and all the elementary particles in this sphere have the same situation as the vortices themselves, or the sphere itself; and hence the vortices, as well as all the elementary particles in the axes themselves, are spheres having a rectilinear arrangement; but those extending from the axes a curvilinear one, or one which is inflected relatively to the axes. The elementary particles in the whole of this sphere or sidereal heaven, do not look to one and the same pole, except in the axis of the sphere only. All the vortices or mundane systems which are in this axis have the same poles, and all the vortices or systems out of this axis have not the same poles, but the poles are according to the situation of the systems in the sphere.

7. There may thus be axes variously inflected, according to the application of neighbouring or surrounding vortices. If the axis of a vortex be inflected, the spiral gyrations along the equators of the parts, or zodiac of the vortex, are not circular but elliptical. The active centre cannot be in the middle of the vortex, but is in one of its foci. If the axis be variously bent, then at various distances from the centre there are various ellipses, or there are various eccentricities relatively to the active centre. The planets move elliptically in a vortex of this kind, the axis of which is variously inflected; and their sun is not in the middle or centre of the vortex, but situated variously in one of the foci.

All the vortices which are directly in the axis of the sphere or sidereal heaven, are not inflected as to their axes; but their gyrations are spirally circular, and their centre is in the middle; but round the axis, where they begin to be circumflected, their gyrations are elliptical, and their active centre is in this case not in the middle; hence there are different and numerous eccentricities. Consequently our solar vortex is not in the

axis of the sphere, but near the axis, where there is a considerable curvature or inflection.

8. The common axis of the sphere or sidereal heaven seems to be the galaxy, where we perceive the greatest number of stars. Along the galaxy all the vortices have a rectilinear arrangement and series, and cohere as to their poles ; in like manner, they are more intimately associated there, and have spires of greater curvature The other solar or stellar vortices afterwards proceed from the axis, and are bent in different directions ; but nevertheless all have reference to that axis.

9. No change can occur in one vortex, which is not in some measure felt in an adjacent vortex, as well as in all the rest as far as the axis extends, and therefore throughout the entire sphere.

10. The skilful geometrician from a given eccentricity and elliptical figure at different distances from the centre may infer the situation of the neighbouring vortices, and the bendings of the axes, and on the contrary from a given situation and distance of neighbouring vortices, he may infer what spiral gyration may exist at different distances. Thus from given ellipses or orbits of the planets, he may know the bendings of the axis, as also the situation of the neighbouring vortices, together with various other particulars.

11. There may be innumerable spheres of this kind, or sidereal heavens, in the finite universe. These may be associated one with the other, like the spheres of two magnets ; and the whole visible sidereal heaven is perhaps but a point in respect to the universe.

CHAPTER II.

THE DIVERSITY OF WORLDS.

1. No world can exist, rich in the variety of its phenomena, without first passing through a succession of states and of intervals of time ; through a succession of changes and con-

tingencies; through modes or modifications; through series of successive, simultaneous and coexisting phenomena; also through connections of series, and repeated separations and connections; whence arises the perfection of its compositions. The greater the number of changes and contingents which concur in its formation; and the greater the number of modifications and existences of things successive, simultaneous and coexistent resulting therefrom, the more perfect the world; or perfection becomes greater also in proportion to the extent of the series and the manifold connection of the various series.

2. The world subsists by the same series by which it exists; and, in regard to its subsistence and existence, has perpetual relation to its primary. The more perfectly the world exists and subsists, the better can it regard its primary, consequently the more perfect and beautiful it is in its direct series than in its indirect; in composite and connected things than in those that are simple and separate: in series having a larger and freer motion, than in those in which it is less so.

3. The changes and contingents may be infinite, and also the varieties of modifications; and, therefore, infinite genera of entities may be simultaneously and successively formed, and afterwards brought into connection; consequently, infinite series of these entities. If the world consists of a series of parts and compositions simultaneously and successively arising, there may be as many series as there are worlds, or as many worlds as there are series; and thus no world can be absolutely like another. For no changes, contingents, modifications, or entities capable of modification, can be assigned as absolutely similar to one another.

4. Nevertheless, in every world-system, the principles of geometry are the same; and also nature and mechanism, as to first principles and motive forces; the diversity consists only in the diversity of the series, in respect to degrees, ratios, and figures.

CHAPTER III.

THE FOURTH FINITE.

WITH regard to this fourth finite, we say that it is similar to the third; that the third is similar to the second; the second, to the first; the first, to its simple or point; and, consequently, that the fourth is similar to all the finites and to the point. Its motion is therefore similar; it can be similarly passive, and constitute the surface of any particle: and can also be similarly active. Its attributes, essentials, and modes, are similar to those of the third finite; it differs from it only in dimension, and, consequently, in degrees and moments. Its origin also is like that of the preceding finite, for it arises from the second elementary particle in the same manner as the third from the first elementary particle. The cause and place of its origin are similar; that is to say, it is near the solar active space, where the second elementary particles were equally capable of being compressed into finites.

CHAPTER IV.

THE UNIVERSAL SOLAR AND PLANETARY CHAOS.

1. THE second elementary particles, by reason of the same causes, are most highly compressed near the solar active space; and, in consequence of this compression, they cease to be elementaries. Finites exist in the same manner as first elementaries; but these finites of a higher dimension exist from second elementaries, and are the fourth in order, the former being third in order.

2. Although all finites possess this power of self-activity, nevertheless, those which have their origin near the sun are not capable of becoming actives, nor of entering into the solar

space to its actives, in consequence of a difference as to velocity, circles, and mass. But the actives which may have been casually made, at once cease to be actives, and necessarily remain mere passives round the solar space of the actives ; consequently, the functions they there perform are those of a guard, to prevent the other finites of the same kind from penetrating into the solar space, and thus from any longer projecting themselves into it.

3. In this manner the number and quantity of finites of the fourth kind increase more and more, by reason of the successive compression of the elementaries; and they also become compact round the solar space. These finites thus formed an immense volume, and crowded around and enclosed the sun in such a way as to form an incrustation ; nor do they cease to act till the vortex is fully formed.

4. Nevertheless this crust, formed round the sun, and consisting of fourth finites, is carried round by a kind of revolution. It is thus representative, as it were, of an active centre in forming and perfecting the vortex, round which, consequently, the elementaries could nevertheless flow in a vortical current, but with a potency and force different from that which they would possess in case the solar space acted simply and contiguously upon the circumfluent elementaries. The whole of this immense crust, together with the enclosed solar space, is not unlike an elementary particle; for in each elementary particle there is an active space, exteriorly to which flow the finites. Thus, both as to figure and motion, this chaos is, on an immense scale, an effigy of each individual part of an elementary particle. Thus nature is similar to herself in her largest as well as her least productions ; and thus she appears in her most stupendous proportions, as well as in her most minute.

5. This incrusting matter, being endowed with a continual circular motion round the sun, in the course of time removed itself farther and farther from the active space; and in so removing itself, occupied a larger space, and consequently became gradually attenuated, till it could no longer cohere throughout, but burst in some part or other.

6. The solar crust, being somewhere broken up on the admission of the vortical volume, collapsed upon itself; and this toward the zodiacal circle of the vortex, or conformably to the situation and motion of the elementary particles; so that it surrounded the sun like a belt or broad circle. This belt, which was formed by the collapse of the incrusting expanse, revolved in a similar manner; removed itself to a greater distance; and by its removal became attenuated till it burst, and formed larger and smaller globes; that is to say, formed planets and satellites of various dimensions, but of a spherical figure.

7. This incrusting expanded matter might subside partly into itself, and thus consist merely of a volume of finites. It might partly subside inwardly, or toward the solar space, and thus revolve round some active space. It might partly subside exteriorly or toward the vortex, and thus enclose a volume of elementary particles. Thus there might exist bodies of three different kinds, namely, planets, satellites, and erratic bodies straying round the sun, such as we are accustomed to call sun spots. It therefore follows, that these bodies, separated into globes, consisted of fourth finites; that they directed their course into the vortical current according to their size and weight; that they continued more and more to increase their distance from the sun, until they arrived at their destined periphery or orbit in the solar vortex, where they are in equilibrium with the volume of the vortex.

CHAPTER V.

THE ETHER OR THIRD ELEMENT OF THE WORLD.

Every planet, therefore, however great, is nevertheless such as the finite is; or it is merely a large finite; the difference between the two consisting only in degrees and dimensions. If, therefore, a planet derives its similitude from its own finite or its individual parts, it does so more especially in regard

to its tendency to a similar motion, or a similar intrinsic and progressive motion, and a similar axillary motion. Planets having become active by their local motion round the sun enjoy the same motion as an active.

1. The fourth finites, of which the infant earth consisted, could not possibly actuate or finite themselves any further; that is to say, they could not form themselves into similar larger finites, except near the surface; not, however, between the surface and the centre, because here they had no room to unfold themselves. Even near the surface they could not actuate themselves, because the vortical element or first elementary particles flowed round, pressed upon and impeded them, and whenever they were set free, immediately absorbed them. The earth thus floated in an elementary volume, or in the vortical element of the sun, by which alone it was now enveloped and equally pressed on every side.

2. These fourth finites flowed more freely near the surface of the earth, and there only could dispose themselves and have free scope for any given motion; this is a consequence of the former proposition. They were, therefore, occupied there by the particles of the circumfluent element, and formed into new elementary particles, which interiorly contain a small volume of the particles of the first element, the fourth finites constituting the surface; that is to say, those finites of which our new orb consisted. These new elementary particles are the same as the ether. In course of time there arose a large number of these elementary particles or ether; for a large volume of elementary particles may arise from a small volume of finites; and therefore the new earth experienced a considerable diminution at its surface before the whole sphere of the ether became perfectly formed around it.

3. Because this new earth continually rotated round its axis, and exposed its whole surface once every day to the sun, these new elementary particles took their rise all over the surface, were generated over the whole circumference,

and did not proceed from one part more than from another; whence the earth, however, diminishing at the surface, retained its spherical or elliptical form; and since it had, as stated, an axillary rotation, the elementary particles recently produced were at once, together with the earth, carried into a certain motion, and bound together, as it were, by that motion, were distributed around the globe, nor did they suffer themselves to be carried away to any other part, and this was the case until it grew from its least to its greatest form.

4. The ethereal particles are much larger than the first and second elementary particles. The two kinds of particles differ also in this respect, that the ethereal possess an internal space consisting not of actives but of elementaries, while the first and second elementary particles consist of pure actives. Consequently, the two kinds of particles are not similar in figure, but the ethereal are perfectly spherical, while the first and second elementaries have poles or polar cones.

5. These new spherical particles cannot but be in perpetual motion. The first enclosed elementary particles arranged themselves in every way suitably to the motion of their composite or the ether, and with a greater exactness proportionate to the amount of motion in the ether; that is to say, their arrangement is according to the degree of motion, and in order from the centre to the circumference. Of the elementary particles thus enclosed, those at the centre are more expanded than those near the surface. The first elementary particles so enclosed lay in a perfectly natural situation, and always the more so, the more intense the motion. In this situation they did not feel the motion of the superficies, or the whole particle.

6. The ethereal particles thus formed can subsist under any kind of motion, and with perfect aptitude to it; their surface is expanded and kept in equilibrium between two forces, or undergoes as much from without as from within.

7. The ethereal particle thus formed and equilibrated is most highly elastic, and hence deserves to be called elementary. Its elasticity, however, is due to the enclosed first elementary

particles, in which the primitive elasticity is latent. By the aid of the enclosed elementaries it is capable of expansion, compression, and of yielding. It derives its elementary nature from the first elementary particles, and is thus endowed with the character of an element.

In every degree of compression and expansion it is nevertheless perfectly spherical, and the more so in proportion to the greater degree of motion which it experiences.

8. The ethereal particles and the first elementaries differ in this, that in a higher degree of motion the former expand themselves more and more, as it were, and become less elastic, and consequently offer a great resistance to any external force. On the contrary, in a higher degree of motion the first and second elementaries are more compressed, and when compressed, they become less elastic, and in this case also offer a greater resistance to any external force; consequently, the expansion of the particles of ether has a greater tension in a greater motion, and less so in a less motion. That the tension of these particles is always proportioned to their degree of motion, and consequently in every degree they have a greater or less tension.

9. Under every degree of extension and compression the ethereal particles are most highly mobile; and in their state of tension are most highly active.

10. Both by their tension in their greatest state of motion, and the compression caused by an incumbent weight, they are able to attain such a degree of resistance that they become more elastic, but, like rigid bodies, resist every compressing or opposing force.

11. These particles can expand without motion, and during this expansion they are not rigid but elastic. The more they expand and the less their activity, the more elastic and yielding they become; and the more they are compressed, the less elastic are they.

12. In the highest degree of expansion the elementary particles may be broken up, and cease to be elementary; but nevertheless the finites, inhering in their surface, and which

are now escaping by reason of the disruption, cannot actuate themselves, but must fall into some of the surfaces of the neighbouring particles, and there, like finites, continue their motion as before in some other surface; so that by the dissolution of the particles and their falling into the neighbouring surfaces, there is imparted to these surfaces the power of expanding themselves further, and occupying more space, so far as the quantity of enclosed elementaries permits.

13. The fourth finites constituting the surface of the ether, have a perfectly regular arrangement; extending by continuous spirals from one polar point to its opposite; and by reason of this arrangement there is a mutual connection between them; consequently, any motion received by this surface must necessarily, in virtue of the contact and arrangement of the parts, diffuse itself around instantaneously, and occupy the whole surface of the particle at one and the same time. In consequence of this spiral arrangement of the parts at the surface, these ethereal particles come to rest with difficulty; more particularly when rendered more rigid by motion; in which case they revolve with the utmost rapidity round a centre, in the same manner as the first and second elementary particles round their axis.

14. The surface of an ethereal particle may be doubled, tripled, or multiplied in various ways within, and this too during its state of compression; but the part of the surface which recedes toward the interiors is differentiated into a new spherical formation, each sphere being similar to the larger; and in a greater degree of compression, the spheres thus formed within are multiplied, and, being thus multiplied, thus dispose themselves from the surface toward the centre. It therefore follows, that these ethereal spherical particles exerting tension within, in the state of expansion of the ethereal particle, are again set free, and recede to the surface, and enter into the expanse. It follows also that, in its highest degree of compression, the entire ethereal particle is at length occupied from the surface to the centre by similar small spheres, and

thus ceases to be both elastic and elementary, becoming hard and similar to a kind of material finite.

15. With regard to the elasticity of the particles, it follows from what we have stated, that the elasticity of the volume is the same as the elasticity of each particle; that the elasticity of a lower volume is equal to the weight of the whole of the higher volume pressing upon it, because the two exert pressure and are themselves pressed in proportion to the weight of other particles; and it is in consequence of this that they recede into themselves in the manner previously stated; in order, therefore, that they may sustain the superincumbent weight, their elasticity must be equal to the force and weight of the superincumbent volume. It follows, also, that the elasticity of the compressed volume of these particles is to the elasticity of the expanded volume reciprocally as the volumes; and thus that the elasticity of the compressed volume is rendered stronger than that of the expanded volume, in proportion to the mass or weight of the incumbent volume. But still it does not follow as a consequence that the density of the lower volume of ether is proportioned to the density and weight of the superincumbent volume.

16. The ethereal particles mutually press one upon another according to the altitude or weight of the superincumbent volume. Their pressure is exerted equally in all directions, upwards, downwards, and obliquely. Their pressure is also proportionate to the side or area at any given angle. The elastic force of the particle is exerted also in every direction. They exert also a similar pressure upon the interior parts of any hard body, the pores and interstices of which they are able to enter and permeate. It is in this way that they keep the smaller parts in connection with one another.

17. The motion of the volume of the ethereal particles is the same as the motion of the particles individually. This motion is perfectly equal in all directions; differing in this respect from the motion of the volume of the first and second elements. Every particle contributes its own share to the

motion of the volume; and, therefore, from the figure and mechanism of the particle we may ascertain the nature of the motion of the volume of particles, and from the figure and mechanism of the motion of the volume, the nature of the particle.

18. Particles moved in volume nevertheless preserve their equilibrium with one another in their relative situations, and cannot be forced out of their equilibrium or natural state by any general motion. Consequently, in a single volume in motion, there may exist innumerable other volumes, and indeed equal to the number of centres or causes of motion, or to particles. Nevertheless, every single volume arising from motion from its centre, diffuses itself and is formed with perfect uniformity and similarity, according to the geometry of the parts: that is to say, spherically.

20.[1] If a volume of ethereal particles flowing from any centre against unbroken equidistant surfaces, passes through any hard body or its somewhat free passages, so that the motion of the flowing ether may be continued from the other side in such a way as to maintain the same course and action, then the body is in this case transparent. If the volume passes through unevenly, so that the motion is continued from the other side variously, the direction of the current undergoing a change, then the body is white in colour. A volume in motion extends itself directly from the centre like radii; and where it cannot penetrate, it is reflected, and this too at a certain angle; just as all other elastic spherical bodies are deflected from any other elastic or hard body; if, however, the volume passes through it is inflected and refracted at the same angle of incidence. Within one volume in motion there may be similar and dissimilar motions, or motion concordant and discordant, or more or less harmonic; and all these may similarly traverse the parts of the eye, and be present to the soul simultaneously and similarly.

21. Motion diffused from a given centre through a contiguous

[1] This is the numbering in the photolithograph MS.—*Tr.*

medium, or volume of particles of ether, produces light; for as a result of this motion the ether is reflected from every particle it meets with, and thus the form of an object is presented to the eye. The central motion of the particles of the ether produces not only a rigid expansion of every particle, but also heat; and if this motion be urged from the centre to the circumferences, it causes light together with heat. If, however, it is urged from centres toward circumferences so as to become a local motion, but without the central revolution of every particle, it occasions light minute bodies without heat. There are corpuscles which resemble a kind of effluvia, and which are so small as to be able to move only a volume of ether, but not a volume of air; these, if spontaneously moved, excite light to a certain distance. If they are not spontaneously moved, but put in motion by means of the vibration of the parts in any hard body where they are, then also light is produced, and also electricity, so long as the vibration continues.

CHAPTER VI.

THE FIFTH FINITE.

It must have originated where there was a quantity of finites of the fourth kind, and where the latter could in some measure unfold and mutually finite themselves. And because these fourth finites could now be only in the planets or here in this earth, and could unfold and finite themselves nowhere else but at the surface of the earth, and not even between the surface and the centre, because they had no room for unfolding themselves, it follows that these fifth finites must have originated at the surface of the earth, at some distance from the sun, where the pressure of the vortical element was not so great as it was in the vicinity of the sun.

CHAPTER VII.

Air on its surface consists of fifth finites, and within it are enclosed the first and second elementary particles. Air is thus very similar to ether, from which it differs only in degrees and dimensions. As regards their locality, the ether and air particles have a similar origin, that is, they are near the surface of the earth, where, as we have stated, the ether particles had their origin. As to the mode of origin of air particles, it is similar to that of the ether particles, that is, among the first and second elementaries. The air and ether particles are consequently similar in form, and differ only in magnitude and dimension.

1. In the course of time there was produced a large number of these elementaries or air particles, since from a small volume of finites a large volume of these elementaries may originate; and with a continual decrease of surface our new world becomes considerably decreased in magnitude before the whole atmosphere around it could be perfectly formed.

Similar things may be said of the air as of the ether, see chapter v. paragraphs 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18.

CHAPTER VIII.

FIRE, OR THE ACTIVES OF THE FOURTH, FIFTH, AND FOLLOWING FINITES.

1. Finites of every power and dimension may put themselves into activity, provided they have space for so doing, or for running freely, naturally, and without retardation into their respective circles; provided also they are not implicated in any elementaries flowing around, and become convoluted into surfaces or new ball-like superficial or elementary particles.

2. There are no actives belonging to the third finite, but all are themselves third finites, and constitute the surface of the second elementary particle. Actives of the fourth kind constitute subtle elementary fire, and actives of the fifth finite constitute common fire.

3. With these actives coincide those treated of in part i. v. 7; vii. 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19; also v. 8, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22; vi. 14, 27, 28, 29, 30.

4. With regard to the active of the fifth finite, it is no other than the fifth finite itself set at liberty in a space where it can move freely, like the foregoing actives, in eccentric circles and gyres, and by means of which it may form, as it were, those continuous surfaces, and by its weight and impetus act upon whatsoever it meets. These fifth finites, however, constitute, for the most part, the surfaces of the particles of air. This active is nothing more than the fourth finite set at liberty, or in a space where, like the preceding actives, it can move freely, in eccentric circles and gyres, by means of which it may form, as it were, continuous surfaces, and by its velocity and mass or weight act upon whatsoever it meets; but these fourth finites constitute, for the most part, the surfaces of the particles of ether, and occupy the central globe of the earth.

5. The fifth finites cannot become active so long as they occupy the surfaces of the air particles; and if by chance they should be set free from the surfaces, in consequence of the expansion of the air particles, they cannot become active without immediately lapsing into the surfaces of the other particles of air; and there, together with their like, performing a general motion, the same as the fourth finites do in the surface of the ether particles.

6. The actives of the fifth finite cannot form any active space except among the air particles, by which the space is enclosed and bounded on every side. Consequently, they can form no space among the particles of ether; still less among the particles of the more subtle elements, such as those of the first

and second. These actives cannot have any boundaries, but become immediately dissipated unless enclosed by air particles. Similarly the actives of the fourth kind can form no space except among the ether particles—not among the air particles, nor among the second and third elementary particles—otherwise they would be immediately dissipated.

7. The space formed by the actives of the fifth finite in the volume of the air particles cannot continue to subsist, unless it be continually supplied with a fresh quantity of actives; that is to say, unless the active space be continually supplied with fresh material. Otherwise the actives are immediately occupied by the first and second elementary particles, are converted into air particles, or pass into the surfaces of the surrounding air particles, and so perish and become dissipated. Similarly the space formed by the actives of the fourth finite in the volume of ether particles cannot possibly subsist unless constantly supplied with fresh actives; otherwise they are immediately occupied by the first elementaries, and are converted into ether particles; or else, passing into the surfaces of the surrounding ether particles, they perish and are dissipated.

8. A large quantity of finites, or of the actives of the fifth finite, enter into the structure and texture of terrestrial bodies, such as vegetable, sulphurous, oily, and other substances: from these, new actives may perpetually emanate and shoot forth into the active space; that is to say, if the bodies previously mentioned are in the very space itself. Numerous air particles also may enter the structure and texture of these bodies, and when these bodies are dissolved, these particles rush into the active space. Air particles, in a state of separation from their volume and merged into active space, become immediately free. All the fifth finites occupying their surface thus become actives: in this manner fire may be abundantly fed by the air. A similar law obtains with regard to the actives of the fourth finite, occupying the surface of the ether particles.

9. The air particles nearest the active space are in the highest degree of motion, and consequently in the highest and most

rigid state of expansion. Such as are farther from the space are in a less degree of motion, also in a less degree of expansion and tension, and this according to their distance from the active space. Similarly the active space cannot subsist unless the air particles are expanded according to their distance from it; that is to say, unless there be formed around the space a sphere of particles gradually less and less expanded and mobile. A similar law obtains with regard to the ether surrounding a space consisting of actives of the fourth finite.

10. The air particles themselves, when excited to the highest degree of motion by means of the actives of their space, give rise to something similar to actives. They produce also something fiery and warm. They also break up the structure of certain parts. Thus, in their state of expansion and motion, the air particles resemble a kind of actives, although in one respect not so; that is, they do not put the volume of ether particles into such motion as to diffuse light.

11. Ether particles can be in the same space with the actives of the fifth finite; but when they are in this space they are excited to a most intense motion; and, consequently, in this state of motion have a high degree of expansion and rigidity. Ether particles thus contribute in a special manner to the amount and increase of heat. The actives of the fifth finite may in their space urge an ether volume into such a high degree of motion, that this volume may give rise to modifications which have the appearance of light. The ether particles also in this space may be dissolved, and the space, thus increased by the actives of the fourth finite, be rendered stronger and larger. Finally, the ether may be exterminated in some measure, in proportion as the active space increases in force and extent.

12. The first and second elementaries can be in the same space with the actives of the fifth finite; and do not in any manner disturb their circles and gyrations, but yield to them just as the atmosphere yields to any weight, gyrating or revolving within its volume.

13. The force of the active space increases according to the number of the actives in the same space, and in proportion to the addition of the actives of the fourth finite to the number of the other antecedent finites.

14. The space consisting of the actives of the fifth finite has no weight except what is imparted to it by the volume of first and second elementary ether particles forming the contiguous extense in this space. This space, moreover, has no determinate situation except that which is determined by the enclosed elementary and ether particles, and by the air particles, which, having became lighter by their expansion, flow freely.

15. Actives of the fifth finite act by degrees and impetus upon the various objects they meet, and dissolve their connection. The ether particles also, which are in a state of high velocity, act upon them by their central gyrations and their activity resulting therefrom; as also by means of their expansion. The space itself, also, by reason of its lightness, acts upon the connection of the harder bodies, and dissolves them by reason of the equilibrium and the amount of its pressure on both sides; that is, both within and without the structure of the bodies. Numerous cases may thus assist in the resolution of bodies by fire in an active space. Now, because the active space cannot subsist except by means of new actives, which perpetually enter into the space and so constitute it, it follows, that it cannot subsist unless it be always replete with parts of the same kind, and which the actives previously mentioned supply by their dissolution. So that the space must thus be crowded with sulphurous, oily, saline, vegetable, and many other kinds of particles; for which reason the space can extend no further than the tide of these particles from which the actives come. It follows as a result that this igneous space may be rendered stronger and weaker in its action, according as the parts floating in it supply a smaller or larger quantity of these actives.

16. The space consisting solely of actives of the fourth finite and enclosed by the volume of ether, can pass through the

atmosphere with a perfectly free current; it may, as it were, cleave through and penetrate even the hardest bodies; it may in its passage break up and disintegrate their more subtile connections, and give rise to more phenomena than the space formed by the actives of the fifth finite.

17. It is of these fourth finites that the central globe of the earth consists: but they cannot burst forth and become active without being immediately laid hold of by the first elementaries, and converted into ether particles, according to the theory above laid down. If, however, there were a passage leading from the centre sufficiently open for these finites to escape through it, an active space would be formed by that part, at our present distance from the sun; and when formed it might continue to subsist so long as fresh finites constantly emanated and, as it were, germinated into the space. But by means of this space the sphere of the ether would considerably extend, and the earth lose that equilibrium which it now maintains at its present distance from the sun and in its present vortex; and, consequently, it would undergo some remarkable change not only in regard to its position and the orbit it describes in the vortex, but also in regard to its polar situation and axillary motion.

CHAPTER IX.

WATER OR THE PURELY MATERIAL FINITE.

1. A PARTICLE of water is similar to a compressed particle of air, in which there remains nothing elementary, yielding, and elastic, but something hard, consisting of contiguous spherules formed within another larger spherule. The particle of water is not a finite like one of the preceding finites, that is to say, capable of actuating itself, but is one which is purely material: consequently, water is not an elementary particle.

2. Particles of water, or finites of this kind, cannot move among one another like elementaries, unless there are inter-

fluent elementaries to carry these particles with them, and thus set them in motion. The particles of water thus owe their motion and fluidity entirely to the interfluent ether. Aqueous particles are the more mobile and fluid, in proportion as the circumfluent ether particles are the more mobile, extended, and rigid; and the less mobile and fluid in proportion as the circumfluent ether particles are the less mobile, extended, and rigid, but soft, as it were. In proportion to the want of mobility and tension in the ether particles the aqueous particles are torpid and languid, uniting and forming into a hard mass.

3. The ether particles are capable of permeating the interstices of water, but not those of the air, in consequence of their difference in dimension. The air particles are therefore in contact with the surface of the aqueous particles, and press upon them in proportion to the altitude or weight of their volume.

CHAPTER X.

VAPOUR OR THE FIFTH ELEMENT.

1. VAPOUR is formed on the surface of water, and from the motion of the interfluent ether particles. Vapour when formed encloses within itself a small volume of ether; and externally is subject to the pressure of both the ether and the air. The surface is thus kept in equilibrium by forces flowing without and within; and preserves its spherical form under every degree of pressure.

2. Vapour may be compressed and expanded; and it possesses a yielding and elastic surface, but owes all its elasticity to the enclosed ether, and the ether to its enclosed first elementaries. Vapour is, therefore, a particle not fully yielding and elastic, consequently not perfectly elementary, but similar to an elementary, or endowed with elementary properties. The surface of the vapour particle may be variously multiplied; in its state of compression it consists of numerous foldings,

series, and expanses ; in its state of expansion it consists of a smaller number, and thus it may be expanded and compressed according to the influence and state of the enclosed ether and surrounding air.

3. A large volume of vapour may arise from a small volume of water, and this volume may become more and more expanded by the application of heat ; indeed, it may be expanded with such great force and tension, that large weights may be raised, and walls of iron and brass burst asunder.

Particles of vapour forming a contiguous expanse are capable of the highest degree of expansion : the expansion may gradually increase if a constant stream of water be furnished from which new particles of vapour may not only arise and pass into the expanse, but pass from one vapour to another in one continuous stream, ascending from the bottom to the top, and thus may afford room and sufficient means for still greater expansion. And if any portion of these particles bursts as the result of too great an expansion, the water hence arising and passing into the surfaces of the neighbouring particles, always provides them with fresh means for further expansion.

4. Particles of vapour differ from bubbles of water in this respect, that interiorly the former contain only ether, while bubbles contain both ether and air.

5. In every bubble of water there is now contained all that had previously existed from .the first simple, every kind of finites, actives, and elementaries of which we have treated in the course of our present work ; so that in a small bubble the whole of our visible and invisible world is latent.

CHAPTER XI.

THE VORTEX SURROUNDING THE EARTH AND THE PROGRESSION OF THE EARTH FROM THE SUN TO THE CIRCLE OF ITS OWN ORBIT.

1. In the solar vortex formed by the spiral motion of the elements from the centre to the circumferences, the elementary particles are not only reduced to a regular arrangement and motion, but are continually kept in this by the constant action of the sun in the midst. Consequently, there is in this vortex a force or tendency from the centre and to the centre, according as the bodies are lighter or heavier than the volume of the element.[1]

2. The earth continually turns on its axis like a large finite, and spontaneously; that is to say, by reason of the effort of the individual parts constituting its central globe; and thus it began to measure out the intervals of day and night at the moment of passing from the sun. From this moment also it would seem to have performed its axillary revolutions more rapidly than it does at a greater distance from the sun, when a considerable portion of it is consumed in the formation of ether, air, water, and terrestrial matter, and the parts of the earth become more closely bound and connected one with another by means of an incrustation consisting of different bodies.

3. The earth, like a large active, has a tendency to a second motion, or to circles round the sun, by means of which it forms a surface not unlike the previously named actives; still, however, it was carried round the sun principally by the stream of the solar vortex. Hence from the beginning of its journey it was perpetually measuring out, by its circular

[1] This statement and that in 6 does not concur with the theory given on page 123, vol. i.—*Trs.*

and periodical revolutions, winter and summer, spring and autumn, that is to say, years, but of less duration than those of the present day.

4. The earth moving among the elementary particles of the solar vortex, according to its magnitude and the velocity of its motion, formed a vortex around itself, just like the small magnetic corpuscle treated of in the Second Part; consequently, at the commencement of its journey it described first a larger, then afterwards a smaller vortex.

The earth, when thus in the centre of its vortex, was in its natural position; it could not travel beyond its vortex, nor move unaccompanied by the vortex; but so long as its axillary motion remained, so long also the vortical motion of its parts remained, always determined and proportioned to the size and velocity of its body.

5. The vortex formed round the earth aimed at an equilibrium in the solar vortex, that is to say, it occupied the place where it could be in a state of equilibrium. Were the vortical motion more rapid, it would seek a different place from what it would were the motion slower.

This, however, does not prevent the elements of the solar vortex from exerting a pressure within the minor vortex also, in proportion to their altitude, and similarly in every direction. Nor does it prevent them from exerting this pressure, if smaller vortices are formed within the larger: whence from the general pressure of the solar vortex there arises a tendency toward the earth's centre.

6. The greatest motion of the solar vortex was at the centre, and became gradually less as it approached the circumferences, so that it was least or none in the farthest circumference, and this, too, in the plane of its zodiac.

7. The earth, which was compelled to describe innumerable spiral circles in its passage round the sun, travelled with a velocity gradually diminishing in proportion to its distance from the sun. Its motion also decreased according to the circles it described, or its annual revolutions in a simple ratio;

but in relation to the diameter or right line drawn perpendicularly to the sun, in a duplicate ratio.

8. With regard to the velocities in the solar vortex at several distances from the centre, they are in the diameter in the subduplicate ratio of the distances from the ultimate periphery, or that in which all the motion ceases, or by reckoning from that periphery where all motion ceases. Similarly, in the solar vortex the times are [inversely] in the subduplicate ratio of the distances from the ultimate periphery towards the centre. If, however, the vortex be such that the least motion is in the centre and the greatest in the direction of the circumferences, then the velocities and times[1] will be in the [sub]duplicate ratio of the radii from the centre.

9. If two planetary bodies be in motion in the solar vortex, each at a different distance from the centre, but moving in a circle or ellipse round the sun, the squares of the periodic times of each body will be as the squares of the radii divided by the distances or complements of the radii extending to the ultimate periphery. If, however, the vortex be so formed that its least motion is in the centre, and its greatest at the peripheries, then the squares of the periodic times will be as the cubes[2] of the distances from the centre.

10. Two planetary bodies moving at unequal distances from the sun or centre, differ in their velocities; these velocities are as the rectangles of the radii and reciprocals of the times. If, however, the motion increases from the centre to the circumferences, then the velocities will be reciprocally in the subduplicate ratio of the radii.

11. If two planetary bodies gyrate at unequal distances from the solar centre, the centripetal forces are as the distances from the ultimate periphery divided by the radii.

[1] "and times" should be omitted. Times of revolution are the inverse of velocities.—*Trs.*

[2] Here the question whether motion in the solar vortex is greatest at the centre or circumference is left open, and only the requirements needed to make hypotheses agree with facts are stated. Compare with p. 126, vol. i. —*Trs.*

CHAPTER XII.

THE PARADISE ON OUR EARTH AND THE FIRST MAN.

1. A CRUST was formed upon the water by the dissolution of the parts in the water, and the interjection of finites which emerged to the surface, and formed upon the water a crust which continually increased by an addition of parts one under another.

2. The earth underwent innumerable changes before arriving at its present circle or orbit, that is to say, changes as numerous as the circles it completed, or the different distances of these circles from the sun; as numerous also as were the degrees of velocity in the course of its annual and diurnal revolution; in a word, every day and hour it underwent some new change, during its journey from the sun to its present orbit. From all these considerations, however, we are at liberty to infer, that our earth must have undergone innumerable changes before it could have been fully completed, and have consisted of so many series of things simultaneously and successively arising; or before it could have been enriched with so many things as would suffice to supply the mineral, vegetable, and animal kingdoms; before also it could have placed its seeds, unfolded and expanded them, and so delightfully and variously adorned its own surface.

3. During that state of the earth in which its revolutions round the sun and its rotations upon its own axis were more rapidly performed, or when the earth measured out shorter days and years, the whole surface of the earth enjoyed perpetual spring—a season the most highly suited to the purposes of generation and procreation. Without this perpetual spring no seeds would have germinated, nor could the various subjects of the animal and vegetable kingdoms have been produced.

APPENDIX A.

NOTES ON SWEDENBORG'S PRINCIPIA.

ALTHOUGH Swedenborg's treatment of the spiral motion in his vortex relates mainly to the form of the motion, and omits dynamical considerations, yet an approach to dynamics is made in the statement (pp. 118-119, vol. i.) that, "since there is a consecutive series of these points from the centre to the circumference, the motion is retarded by this series at every successive step; and inasmuch as the cause of retardation and resistance is simple, the variation of velocity is simple; so that the greatest velocity is in the centre, it is less in the circumferences, and least in the ultimate periphery."

Here we find the conception of moving bodies, endowed with energy, and whose motion is gradually impeded by a resistance, until it finally ceases. What becomes of this energy? Two views are possible. In one, the centre is to be regarded as a source of energy—the circumference as a sink. The energy is therefore perpetually destroyed and recreated. In the other view, the energy becomes latent by passing into a structure which produces the resistance, whence the energy can be restored into the energy of moving particles by some reversal of the mechanism. Judging from other parts of the *Principia*, where stress is laid upon the necessity of a reciprocating motion, the latter seems to have been Swedenborg's view; but he does not describe the mechanism by which the resistance is produced.

The passage on page 123 which asserts that in a vortex whirling most rapidly at the centre, "a body, heavier than the vortical element or its volume, will be carried from the centre to the circumference; but if lighter, it will be carried from the circumference to the centre," also touches upon a question in dynamics. Swedenborg has borrowed this conception from Des Cartes, in whose solar vortex the denser parts were supposed to be carried away from the centre, those

of less density moving inwards. The hypothesis was perhaps suggested by the centripetal movement of straws in a whirlpool. If Des Cartes had known more about comets, he might have turned his hypothesis the other way, because the very rapid centrifugal development of the tail is produced in matter of the lightest sort. But whichever way the conception may be turned, it fails when brought to face the fact that there are retrograde comets. Halley's comet, as the first of this sort to be thoroughly established as a member of the solar system, has fulfilled a notable service to gravitational theory. The conclusive disproof of the guidance of dense bodies into circles of equilibrium by cosmic whirlpools of an interplanetary medium which is not air, was given by the experiment which proved that in a vacuum all bodies, whether dense or rare, seek the centre, and with precisely the same force per unit of mass. This demonstration had already been made by Newton, but Swedenborg does not seem to have noticed its significance. In a powerful aerial vortex, or tornado, not only light objects, such as straws, but heavy timbers and even stones are taken up and whirled to the centre of the vortex, where the motion is most rapid. Here again, no respect is paid to the supposed law adopted by Swedenborg from Des Cartes. In fact, the bodies, in spite of the very great discrepancy between their densities and that of the air, move with the air in the direction of its current, wherever this exceeds a certain velocity, being held by the grip of the air acting through its viscosity, a property possessed by the air which is very necessary to the success of flying machines of the "heavier-than-air" type.

The necessity for "the help of mechanics" in order to arrive at valid conclusions in regard to physical principles is recognised on page 116; but the mechanical theories employed do not advance beyond a preliminary kinematical stage. It is true that the word "conatus" is sometimes used by Swedenborg in a way which might mean energy in the modern sense of that term; but the need of nice distinctions had not then arisen. His use of conatus to express the unknown cause of motion is less precise than the present conception of energy; but on the other hand, his insight shows him that there are infinite things concealed therein.

The modern doctrine tries to get rid of this difficulty by eliminating essentials; but as all elimination is really only a setting aside of certain terms in an equation, reserving them for future consideration, and as the eliminated terms have to come back at some time, it will be seen that the modern apparent simplification is really only provisional; the necessity for an ultimate consideration of final causes is merely postponed. Dynamics is one step of progress without which the theory of the *Principia* remains incomplete, and in many respects faulty. The dynamical tests show many difficulties which necessitate an almost complete reconstruction of the theory. Its principles have merit, not as a final and successful solution of the problem, but as a first daring venture into the unknown, and as the pointing out of a new road which is now being travelled in chemistry and physics with increasing surety that the goal is in sight.

Some of Swedenborg's attempts to introduce his theory into the dynamical stage involve assumptions which cannot be admitted. The relation, $r : c :: c : v$ (on page 129), is apparently assumed in the effort to account plausibly for a circle of equilibrium, and for a supposed "middle" position of planets in a vortical current; but just as the equation given for the spiral motion admits of no "ultimate circumference," so now the assumed "circle of equilibrium" turns out to be fictitious. The relation that the velocity shall be a mean proportional between the radius and the centripetal force is not sufficient to define a circle of equilibrium, since, as I shall show, the relation adopted makes the centripetal force constant, or is compatible with any radial distance whatever. Moreover, by page 125, the circle of equilibrium depends on a ratio of densities; but this has been omitted in the proportion on page 129. The same thing will be recognized if we state the relation dimensionally; for $r = L$, $c = \dfrac{L}{T}$, $v = \dfrac{ML}{T^2}$[1], when the above proportion states that

$$L^2/T^2 = ML^2/T^2,$$

which is incorrect.

[1] The reader will note that I have made c=velocity, and v=centrifugal force in accordance with Swedenborg's use of the symbols. Nowadays, we should naturally give them the opposite significance.

The statement that "in the vortex in which the motion is greatest in the circumference and least in the centre, the centripetal forces are reciprocally as the squares of the radii" (page 129), is not true; for if $Rc^2 = rC^2$, $c = \sqrt{rC^2}/\sqrt{R}$, and the proportion

$$r : \sqrt{rC^2}/\sqrt{R} :: \sqrt{rC^2}/\sqrt{R} : v$$

gives $$v = rC^2/rR = C^2/R, \text{ whence}$$

$$\frac{v}{V} = \frac{C^2 r}{c^2 R} = \frac{Rr}{rR},$$

or $v = V =$ a constant. Practically the same thing follows from the proportion for motion greatest at the centre, or $v : V :: lR : Lr$, since $lR/Lr =$ a constant very nearly. It will be noted that in the original, at bottom of page 238, the proportion, $r : R :: C^2 : c^2$, is incorrect, as will be seen by referring to the definitions of r and c given previously, namely: "$ac = r$," "$c =$ the velocity in the circle c."

In Swedenborg's treatment of the first finite (part i., chap. iii., no. 20), he has dwelt upon the necessity for a reciprocating spiral motion. His equations do not give this desideratum. It is necessary, therefore, to supply the deficiency. This may be done if we replace the parabolic spiral,

$$r^2 = b^2\frac{\theta}{2\pi},$$

which fig. 1 is apparently intended to represent, by a spiral whose equation contains a trigonometrical function, such, for example, as the spiral whose equation is

$$r = a\left\{\sin(b\theta + \gamma) - \sin\gamma\right\},$$

which has two branches, namely: a positive branch extending from the pole to a limit $= a(1 - \sin\gamma)$, and back to the origin; and a negative branch continuing to the limit, $-a(1 + \sin\gamma)$, and back; or we may use the sinusoid spiral,

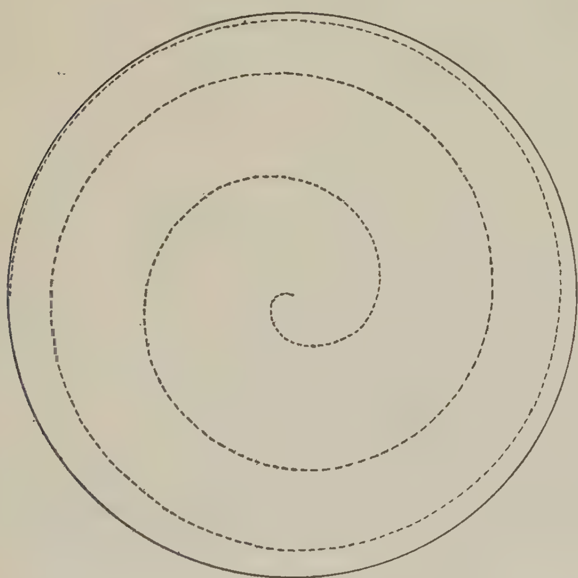
$$r = a\sin(b\theta),$$

where the positive and negative branches are equal and similar. Fig. 1a, which may be compared with fig. 1, page 118, gives three revolutions of a spiral computed with

the values $\gamma = 30^\circ$, $\sin \gamma = 0{\cdot}5$, and $b = 0{\cdot}05$. The constant factor a may be any convenient length, according to the size desired for the figure.

The tridimensional relation cannot be represented so simply. There are some puzzling statements in the *Principia*

Fig. 1*a.*



which may require philosophical explanation. For instance, in no. 17, page 113, the second finite is said to be "as yet scarcely comprehensible geometrically," since "it is only the second boundary. Geometry requires at least three boundaries before it can determine anything by analysis." Is the author talking about dimensions of space? Because he has already introduced the conception of a substantial revolving in a plane, and of a precession of the ecliptic nodes of this revolution along the equator of a composite spherical surface mapped out by the motion in cubical space. Is he not rather making a first attempt at giving us the idea of a trine of discrete degrees as essential to the complete existence of any natural form? In this case the allusion to geometry and its three dimensions is merely metaphorical. At any

rate, the kinematical solution of his vortical motion requires the compounding of motions in three dimensions.

The form of Swedenborg's elementary particles may be shown most clearly by an example. Let the locus of motion in an equatorial plane have polar co-ordinates, ρ, θ, and let the locus of motions in meridional planes have polar co-ordinates, r, ω, referred to a polar axis which rotates in the plane of the equator, pivoting on its centre, the angle ω being zero at the outer equatorial circumference. Let the areal velocity in a meridional plane be

$$(1) \qquad A = 1/2\, r^2 \frac{\delta\omega}{\delta t},$$

$\delta\omega$ being a small angle described in a short time, δt; and let the form of this motion be elliptical, with the least linear velocity near the polar axis of the composite. Here $\frac{\delta\omega}{\delta t}$ is the angular velocity of the radius vector in a meridional plane about an axis in the equatorial plane, normal to the polar initial line of r, ω.

In like manner $\frac{\delta\theta}{\delta t}$ is the angular velocity of a point with radius ρ about the polar axis of the composite. Let

$$\delta\theta = f\,(1/\rho),$$

and calling $(\delta\omega)_M$ the maximum value, and $(\delta\omega)_m$ the minimum value of the meridional circulation, let the maximum value of $\delta\theta$, corresponding to a minimum radius ρ_m, be

$$(2) \qquad (\delta\theta)_M = (\delta\omega)_m \times c,$$

the minimum value of $\delta\theta$ being

$$(\delta\theta)_m = 0$$

at the outer circumference of the composite, where $\rho = a$.

Let the angular velocity of θ at any distance, ρ, from the polar axis be

$$\frac{\delta\theta}{\delta t} = \frac{a-\rho}{a-\rho_m} \times (\delta\theta)_M = \frac{(a-\rho)\,(\delta\omega)_m}{a-\rho_m} \times c. \qquad (3)$$

The radius of the outer meridional motion is supposed to vary between maximum and minimum limits, r_M and r_m, while

(4) $$r_M + r_m = a - \rho_m.$$

At any point (r, θ, ω),

(5) $$\rho = (a - r_m) + r \cos \omega,$$

(6) $$r = \frac{(a - \rho_m) \times (1 - e^2)}{2 \times (1 + e \cos \omega)},$$

e being the eccentricity of the ellipse; and the angular velocities are:

(7) $$\frac{\delta\omega}{\delta t} = \frac{2A}{r^2} = \frac{2A\ (1 + e \cos \omega)^2}{p^2}.$$

where p is the semi-parameter of the ellipse given by the equation

(8) $$p = 1/2\ (a - \rho_m)\ (1 - e^2);$$

and $$\frac{\delta\theta}{\delta t} = \frac{(r_m - r \cos \omega)\ (\delta\omega)_m}{a - \rho_m} \times c. \qquad (9)$$

Introducing the values of p from (8) in (7), and of $\delta\omega$ from (1), as defined, in (9).

(10) $$\frac{\delta\omega}{\delta t} = \frac{2A}{r^2} = \frac{8A\ (1 + e \cos \omega)^2}{(a - \rho_m)^2\ (1 - e^2)^2}$$

(11) $$\frac{\delta\theta}{\delta t} = \frac{2A\ (r_m - r \cos \omega)}{r_M^2\ (a - \rho_m)} \times c.$$

The general equations of the motion are

(13) $$\theta = \delta\theta/\delta\omega \times \omega$$

(14) $$\rho = r \cos \omega + \text{const.}$$

(15) $$r = \frac{1 - e^2}{1 + e \cos \omega} \times \text{const.}$$

(13) defines the rotary motion on which periodicity depends. It is evident from figs. $2a$ and $3a$ that if we have a composite of two rotations in planes at right angles with each other, the state of the rotation at a given time is equally defined if we

take the angle θ as a fixed quantity and compute the rotation, $\delta\omega \times t$, or with the angle ω fixed, find the rotation $\delta\theta \times t$,

Fig. 2a.

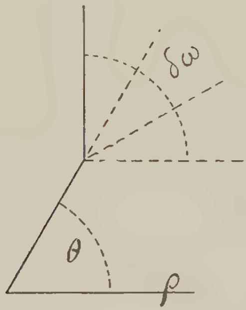
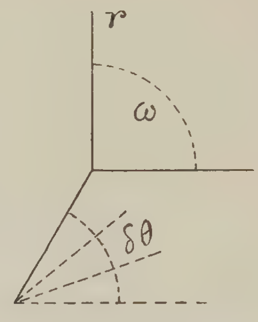


Fig. 3a.



according to the variation of the time. The rotary condition is represented by the equation

$$\theta t.\ \delta\omega = \omega t.\ \delta\theta$$

or

$$\theta/\omega = \delta\theta/\delta\omega.$$

The differential of θ/ω being

$$d(\theta/\omega) = \frac{\omega d\theta - \theta d\omega}{\omega^2},$$

and $\omega\delta\theta - \theta\delta\omega$ being zero at the limit,

$$d(\theta/\omega) = 0,$$

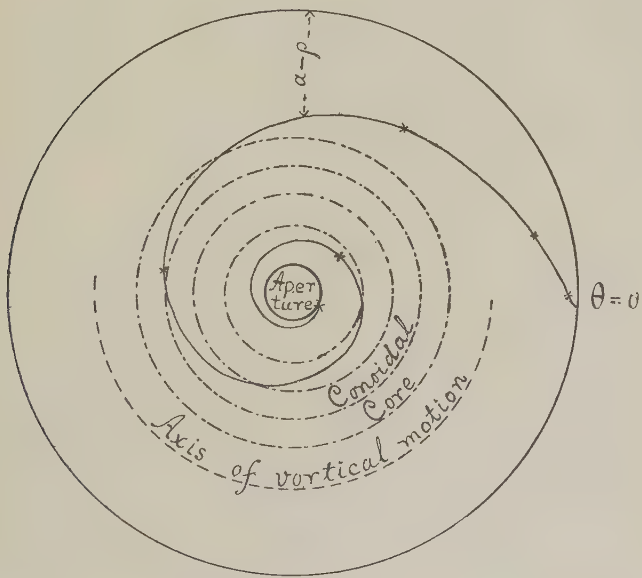
which expresses the fact that neither rotation has any component in the plane of the other. This, while not dynamically defensible, permits a kinematic simplification of the problem.

A corpuscle may be regarded as a volume having an outer surface conditioned by the values of r_M and r_m, and the laws of the motion. The resultant angular velocity of a point in the surface, projected on the equatorial plane, depends on ω, and the constant A. Taking ω from $0°$ to $180°$, and substituting numerical values for the constants, I obtain the following table from these surface values: $a = c = 10$; $\rho_m = a/10 = 1$; $e = 1/3$; $r_m = 3$; $r_M = 6$; $(\delta\omega)_m = A/18$; $r = \dfrac{12}{3 + \cos\omega}$; $\rho = \dfrac{21 + 19\cos\omega}{3 + \cos\omega}$; $\dfrac{\delta\theta}{\delta t} = \dfrac{A}{16{\cdot}2} \times \dfrac{9 - 9\cos\omega}{3 + \cos\omega}$:

$\omega =$	0°	30°	60°	90°	120°	150°	180°
$\cos\omega$	1·0	0·866	0·500	0	−0·500	−0·866	−1·0
r	3·00	3·10	3·43	4·00	4·80	5·63	6·00
	10·00	9·68	8·71	7·00	4·60	2·14	1·00
$\delta\theta \div \delta\omega$	0	0·093	0·467	1·480	3·828	7·718	10·000
$\delta\theta \div A$	0	0·019	0·079	0·185	0·333	0·487	0·556
$\delta\omega \div (\delta\omega)_m$	4·00	3·74	3·06	2·25	1·56	1·14	1·00
$\theta = (\delta\theta/\delta\omega) \times 30°$	0	2·79	14·01	44·40	114·84	231·54	300

By assumption, $\frac{\delta\theta}{\delta t}$ is proportional to $\alpha - \rho$, and the figures in the last line of the next table are proportional to surface velocities of rotation around the polar axis of the corpuscle.

Fig. 4a.



This represents a corpuscle rotating most rapidly at the centre, and one whose resistance to compression will increase as the centre is approached. It therefore fulfils the conditions required by Swedenborg's theory. By assuming larger values for c, a closer coil may be obtained for plotting. For example, if $c = 80$, the figures given will represent distances for successive revolutions, measured on a radius. Figure $4a$

shows a projection of the motion on the equatorial plane, with the value of $c = 10$. As the principle is the same, whether few or many revolutions are included, I have not thought it necessary to encumber the diagram with more detail than is given here :—

θ	0	$\frac{1}{4}\pi$	$\frac{1}{2}\pi$	$\frac{3}{4}\pi$	π	$1\frac{1}{4}\pi$	$1\frac{1}{2}\pi$	$1\frac{3}{4}\pi$	2π	$2\frac{1}{4}\pi$	$2\frac{1}{2}\pi$	$2\frac{3}{4}\pi$	3π	$3\frac{1}{4}\pi$	$3\frac{1}{2}\pi$	$3\frac{3}{4}\pi$
ρ	10·00	7·39	6·22	5·28	4·50	3·85	3·30	2·82	2·42	2·10	1·85	1·65	1·50	1·37	1·27	1·19
$a - \rho$	0	2·61	3·78	4·72	5·50	6·15	6·70	7·18	7·58	7·90	8·15	8·35	8·50	8·63	8·73	8·81

The statement made by Swedenborg (top of page 127), "Hence if, with any velocity which the body ultimately acquired in its fall from the ultimate circumference to some other which is nearer the centre, it moves uniformly through a circle or in a right line, then, according to the well-known rule, it will perform double the space or double the distance in the same time," is apparently an inaccurate description of the fact that *under gravitation* the uniform velocity of a planet in a circular orbit is equal to that acquired in falling from the distance $2r$. The modern demonstration of this proposition is known as Van der Kolk's theorem, and may be found in *Astronomische Nachrichten*, no. 1426.

The error of the statement: "If the motion is least in the centre and greatest in the circumference, then the squares of the periodic times are as the cubes of the distances from the centre, or $t^2 : T^2 :: r^3 : R^3$" (page 128, vol. i.), is easily seen ; for, if $r : R :: c^2 : C^2$, then, since the periodic times are proportional to the radii divided by the velocities,

$$t : T :: \frac{r}{c} : \frac{R}{C} :: \frac{r}{\sqrt{r}} : \frac{R}{\sqrt{R}} :: \sqrt{r} : \sqrt{R},$$

or $t^2 : T^2 :: r : R$.

The proportion for the periodic times when the motion is most rapid at the centre is given correctly. In its final form

$$t^2 : T^2 :: r^3 : R^3,$$

this proportion agrees with Kepler's third law ; but Swedenborg's derivation (emended by omitting the erroneous assump-

tion that the direction of motion depends upon density) would require that each planet should get its velocity by a fall from an "ultimate circumference" at twice the planet's distance, in order that the body may acquire a "middle," or, to be more precise, a semi-radial position. The supposition that particles of an originally meteoritic vortex, composed of small bodies moving in more or less congruous orbits, have coalesced to form planets, is a tenable one. Loss of momentum through collisions being compensated by the increased velocity acquired in falling inward, the resistance of the medium to the motion of the nucleus simply broadens the orbit, or makes it more nearly circular; or, what amounts to the same thing, if collisions are distributed equally around a circular orbit, the orbit becomes smaller without losing its shape. If Van der Kolk's theorem applies to the eventual outcome of a single condensation, a repetition of the process should give a series of planets whose distances (r) are each one-half of the distances (r^1) of the next outer neighbours. That the condition is somewhat approximately fulfilled is shown by the following table:—

Planet.	r	$1/2\ r^1$	$r/\frac{1}{2}\ r^1$
Neptune . .	30·1	?	?
Uranus . .	19·2	15·1	1·27
Saturn . .	9·5	9·6	0·99
Jupiter . .	5·2	4·8	1·08
Ceres . .	2·8	2·6	1·08
Mars . .	1·5	1·4	1·07
Earth . .	1·0	·75	1·33
Venus . .	·72	·50	1·44
Mercury . .	·39	·36	1·08

On the average, $r = 117/200$ of r^1. The acceptance of the hypothesis is therefore possible as a rude approximation, but is not compulsory.

On pages 124 and 125 (vol. I.), as well as elsewhere, Swedenborg repeatedly speaks of the motion of his ideal substantial as

being in "circles," for which it might be proper to substitute *spires*, or *spiral circulations*. Since the same form of expression is used in treating of the planetary revolutions in the cosmological sections, it is evident that Swedenborg is still following Des Cartes, and though improving on the latter's corpuscular theories, Swedenborg has failed to grasp the supreme significance of Kepler's first law. The ellipticity of the planetary orbits, with the sun at one focus instead of at the centre, was the great fact of nature which overthrew the Cartesian doctrine. That we have not yet acquired a consistent explanation of gravitation, in no wise absolves us from the necessity of abandoning a doctrine which does not conform to the facts.

In considering pages 130 to 144 (vol. I.) of the text, I shall make my remarks in the form of critical notes. In these, as well as in what has been said of pages 113 to 129 (vol. I.), no attempt is made to consider the topics exhaustively, but rather to elucidate some points which may be obscure, or to correct some which need to be emended. Similar elucidation is much needed in other parts of the work, but would require, if made at length, a treatise as extensive as the original.

(Page 130, ll. 20-23.) Here, apparently, Swedenborg recognises that the perfect similarity between least and larger forms, which he has elsewhere assumed, may fail owing to breaks in the continuity; and in the next section he proceeds to discuss the first consequences of such broken connections which diminish the likelihood of an exact repetition of the pristine motion in subsequent orders.

(Chapter v.) Curvilinear motion, according to mechanical principles, requires a central force to be acting upon the moving parts. The continued spiring of the free active, and the production of circles in a new order of motion, implies a dual constitution of this entity. Swedenborg asserts the existence of curvilinear motion, but leaves its origin unknown.

(No. 5, page 136.) The argument appears to contemplate: first, a series of contiguous substantials arranged along a plane spiral similar to fig. 1, which are kept in position by the mutual pressure and motion of companions in a "finite," by which is signified a continuous medium, capable, however, of segregation and limitation; and next, a motion within a single component

substantial, produced by unspecified forces, which continues along the same spiral trajectory in miniature as that of the general medium, but which tends to fly off and produce an active. The plane containing the spiral trajectory, "plane of the ecliptic," is either supposed to oscillate, or "progress," to and fro, parallel to itself, in a period synchronous with that of the spiral reciprocation; or else it is supposed to be inclined to the equator of the compound and to have a slow motion of rotation, its normal describing a cone as in the precession of the nodes of the earth's ecliptic, produced by the slow conical movement of the axis of rotation.

Figure 8 represents the flow in a substantial as consisting not only of many particles, but of many series of particles, and does not answer the description in no. 5, which can only apply to a single component particle of the flow, since the mean centre of the full cycle of series is the centre of figure. The same follows from no. 4, where it is said that "one point must necessarily act and press upon the neighbouring one; consequently, upon the whole series, upon all that are connected with it, or contiguous to it." Here a stream of moving particles following each other in single file, confined between similar streams, is meant. But in no. 9, page 139, the active is said to consist of only a single moving point; and the last part of no. 5, stating that "the centre of gravity is in the plane of the ecliptic," obviously refers to the motion of a single component, but one which continues the general motion of the compound. Apparently, the pressure from adjacent restraining particles is still conceived as continuing in no. 5; but preparation is being made for a final tangential release in nos. 6 and 7, where, however, the release is described very obscurely.

No. 6, page 137, seems to contemplate at least a partial relinquishing of the bonds of circumscribed spiral motion and the derivation of rectilinear motions by centres of gravity thrown off tangentially from rotating substantials. Nevertheless, the description continues to treat of rotations, as though the tangential tendency still felt the bond of a central force, a restraint which is incompatible with a completely free and single active.

No. 7, page 138, speaks of actives as "flying off" tangen-

tially, but the subsequent paragraphs recognise a description of orbits and surfaces by the free actives, which is different from what might be anticipated in a free space where ideal rectilinear motions prevail. It should be remembered, however, that we really do not know whether these ideal motions are possible, the curvature of a finite space being one of the debated questions of mathematical metaphysics. We may question whether Swedenborg really accepted Galileo's laws of motion. On page 69 he favours a perpetually circular motion, because it is "the most perfect." Here, however, and at pages 238-239, a remnant of rectilinear motion is admitted.

The words towards the end of no. 6 : "And thus constantly makes some other and new section and node of its gyre with the equator," represent a spiral motion in an ecliptic plane whose normal perpetually describes a cone, resulting in a species of vortex with re-entering polar conoidal depressions. But no. 24, page 75, predicates a complete spherical form described by a perpetual and relatively slow rotation of the ecliptic plane about a diameter of the spiral. This may also be compared with the description of a planetary active, vol. ii. page 308.

In the midst of so much vagueness, it is difficult to get at the real meaning of no. 6. If the inherent motion is essentially spiral, there is nothing to cause tangential motion unless the original motion is resolved and compounded with a new motion. If the inherent movement is rectilinear, nothing can make it spiral or circular but some restraining force of which there is no hint, since the actives are no longer in mutual contact, and nothing is said of any force acting at a distance.

If it be permissible to assume that no. 7 is treating of active particles thrown off tangentially from a rotating finite, then the paragraph asserts that the angular velocity increases for the narrower gyres in such ratio that the tangential velocity remains constant, as it was shown to do in the supposed form of motion (footnote, page 129). The actual properties of matter indicate that vortex atoms contain opposing rotations. (See the researches of W. M. Hicks, F.R.S., in vortex motion, especially that "On Spiral or Gyrostatic Vortex Aggregates," *Proceedings of the Royal Society of London*, vol. lxiii.

page 332, February 3, 1898.) Hence the foregoing, while permissible as a speculation, does not appear to harmonise with what is now known of elementary properties. The spectroscope reveals in free atoms the presence of a great number of oscillations of diverse intricately related frequencies. These may be due either to vibrations of the components of a complex configuration of electrons about a mean centre, or to revolutions of satellite electrons around a primary; but in any case the vibrations, or the revolutions, are exactly timed and perfectly distinct. The orbits (if such they be) do not coalesce by insensible gradations as in the gradual change of a continuous spiral circulation, but are clearly defined by their definite periods, and are separated from each other by wide gaps. The spiral theory agrees better with the damped vibrations of incandescent solids and liquids, or of particles which are not free, and seems to be inapplicable to free particles, or actives. This is in harmony with no. 12, page 141, where the internal motion of the confluent particles in a finite is said to be restrained and in a series, and is distinguished from "local motion." The finite is indeed said to have "*no* local motion . . . except in a series," while the active has "none but local motion." It would appear from this that the gyres and circles of no. 6 refer to the motions of particles still confined in a finite, and that the particles do not acquire "local motion" until they emerge tangentially from the finite and invade the free surrounding space. By page 132, the second finite is said to have taken "its origin in some volume of substantials which were in contact with one another, but that the active existed from no such volume of which the parts were in contact one with the other." The passage goes on to discuss the difference between these two, namely, the second finite consisting of confluent first finites, and the active of the first finite: "This mode can produce only the following result; that the coexisting finite shall consist of a certain volume of substantials confluent by their motion into some new finite, but that this new finite [which is the *active*] shall run not in the volume, but outside the volume, without any consociates, into the same figure of motion." The phrase, "into the same figure of motion," is liable to mislead into the erroneous conception that the active

continues to move in identically the same manner as before. But if we combine this statement with that of nos. 6 and 12 of chapter v., we recognise that the active has a new *local* motion which is tangential to its former motion; and hence, if it still keeps "the same figure of motion," it must do so on an immensely larger scale, since its initial curvilinear motion has been transformed into one which is relatively rectilinear, even though it may not be absolutely so, but curves into a circle of large size.

The curvature of the tangent is ascribed (no. 6) to an eccentricity in the perpetually revolving internal structure, or "axillary motion of the whole compound," from which the active was derived. Since no cause has been assigned for this internal revolution or its figure, which is assumed (no. 2) as an unknown, only to be recovered through its reappearance in an image on a larger scale at some subsequent point in the series of successive orders by the law of similitudes, it must be admitted that the hypothesis does not rest on a very secure foundation. Nevertheless, it must also be admitted that the continual reappearance of vortical motion on a larger and larger scale in free emanations, in the magnetic phantom, in the curved polar filaments of the solar corona, in the wonderfully rapid curvilinear emanations from *Nova Persei*, and finally in the spiral nebulæ—features which in many respects are still enigmatical—gives a seeming basis to this part of the speculation.

In his introduction to the second volume (Cosmologica) of the edition of Swedenborg's scientific works now appearing under the auspices of the Swedish Royal Academy, Professor Arrhenius says, in comparing Swedenborg's vortices with those of Des Cartes: "In Swedenborg's work no other change is made in these conditions than that the number of particles is increased and an attempt made to derive all of them from the mathematical point. This section is not of particular interest" (page xxv). While Arrhenius may be right in emphasizing the importance of Swedenborg's contribution to cosmology, as distinguished from his physical theories, it does not seem to me necessary to discredit his merits in formulating a working hypothesis of several distinct orders of elementary particles, and of their vortical nature. Swedenborg

is surely the originator of the doctrine now called by the name of the vortex-atom. It is true that we have no examples in nature of the *kind* of vortex which he predicated. There may be such things as enormous ether vortices, but they are not competent to move the planets as he and Des Cartes supposed. Granting the existence of large ether vortices (which is still somewhat problematical), their origin must be attributed to the moving planets exerting a slight drag upon the medium. This, of course, assumes that there is a viscosity in the ether, though doubtless of an exceedingly small order. We can study liquid vortices, but their velocities are proportional directly (when forced), or reciprocally (when free) to the radius. The law of proportionality of the velocity to the *square* of the radius does not enter. We know something about aerial vortices (smoke rings). They give us the clue to a possible mode of motion in the ether from which matter originates, and we have glimpses of series—electrons, atoms, molecules—representing successive compoundings of entities having different orders of magnitude. The experiment of Michelson and Morley shows that there is a shell of bound ether attached to the earth and accompanying it in its motion through space, and thus there is an analogue to Swedenborg's ethereal atmosphere encompassing the aerial atmosphere of the earth; but the bound ether is not functionally different from the interplanetary and interstellar medium which Swedenborg (part i., chap. vi., no. 50) calls the first element, and which he says conveys light "from the remotest stars"; nor is there evidence that light exists in any other medium than the ether, or that there are discrete degrees of light, corresponding to successive natural atmospheres. Hence, while there may be numerous atmospheres, it is a confusion of function to distribute one phenomenon through several media.

Since Swedenborg's studies of the magnetic phantom were probably at the bottom of his speculations concerning spiral motions, one can but wonder why he did not conform his vortices more nearly to the pattern suggested by the phantom. This has been left to modern investigators, and thus, while the first conception of elementary particles formed by vortical motion of a sort is attributable to Swedenborg, he has failed to hit upon the most probable form of this motion, as far as

we are able to judge from present information. In saying this, I would not deny the possibility that something like the mode of motion which Swedenborg has described may exist in certain least forms which are still beyond our cognizance; but if there are such forms, they constitute a contradiction of his favourite doctrine that nature is similar in great and small things, a doctrine which he may, indeed, have pushed too far.

While seeing its flaws and pointing them out freely, the *Principia* still remains for me a grand book in spite of its defects. The great master-principles of the work loom large as mountain peaks above the mists of these obscurities and blemishes, and excite in me a feeling of profound respect and admiration for Swedenborg as a scientist. His hypotheses may have to be modified so as to be scarcely recognizable. Some of them must be abandoned entirely; but nothing can dim the glory of this magnificent dash into the unknown. It will stand alongside of the sublime poem of Lucretius, which no one accepts as a true picture of the cosmos, but which will remain as one of the monuments of a heroic struggle of the philosophic intellect to reach freedom.

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APPENDIX B.

Bibliographical Notices of the Principal Authors Cited.

Boyle (Robert), one of the founders of the Royal Society, was born at Lismore Castle, Munster, on January 25, 1627. After travelling on the Continent, he settled at Oxford, where he made important improvements in the air-pump, and performed a series of valuable experiments on the properties of air. His name is perpetuated in the well known Boyle's law. Indeed, his experiments are among the most useful contributions to the science of physics, and were among those which Swedenborg used to "trace out nature in its least things." He wrote many works on Theology, and founded and endowed the Boyle Lectures. He died December 30, 1691. Besides his many communications to the *Philosophical Transactions*, his chief scientific works are as follows:—

1. *New experiments, physico-mechanical, touching the spring of air and its effects.* Oxford, 1660. Also 1662 and 1682.
2. *Some considerations touching the usefulnesse of experimental philosophy.* Oxford, 1663, 1671. Also 1664, and, in Latin, 1692.
3. *Experiments and considerations touching colours.* London, 1664. Also, in Latin, 1671.
4. *New experiments and observations touching cold.* London, 1665. Also 1683.
5. *The Origine of formes and qualities according to the corpuscular philosophy.* Oxford, 1667. Also, in Latin, 1688.
6. *Tracts about the cosmical qualities of things, the temperature of the subterraneous regions, and the bottom of the sea.* Oxford, 1670.
7. *A Continuation of New experiments, physico-mechanical*

Oxford, 1669. The edition quoted by Musschenbroek. Also Part II., in Latin, 1682.

8. An essay about the origin and virtues of gems. London, 1672. Also, in Latin, 1673.
9. *Essays of the subtilty and determinate nature of effluviums.* London, 1673.
10. *Experimenta et observationes physicæ.* London, 1691. The work so frequently quoted herein.

Boyle's collected works were published as follow:—An incomplete edition during his lifetime, entitled, *Opera Varia.* Genevæ, 1677. This was reprinted in 1680, of which edition Swedenborg had a copy. After the author's death an edition of his whole works was published at London, 1699, 1700, 3 vols.; also 1744, in 5 vols., edited by Dr T. Birch; and again, 1772, in 6 vols. But the work mostly used by Musschenbroek, and quoted herein, is *The Philosophical works of Robert Boyle, Esq., abridged, methodized, and disposed under general heads*, by Peter Shaw. London, 1725. 3 vols.

FERCHAULT DE RÉAUMUR (RÉNÉ ANTOINE), mostly known under the name of RÉAUMUR, was born at La Rochelle, February 28, 1683. He studied philosophy in a Jesuit college, but afterwards went to Paris to study mathematics and physics, and at the age of twenty-four was elected a member of the Académie des Sciences, in whose *Mémoirs* most of his contributions to science appeared. His appointment to the charge of the official description of the useful arts and manufactures led to many practical researches that resulted in establishing several new industries in France. He invented the thermometer that bears his name in 1731. In 1722 he published at Paris a treatise entitled, *L'art de convertir le fer forgé en acier, et l'art a doucir le fer fondu*, which is cited in another work by Swedenborg, who owned a copy and refers to it in a letter to Benzelius on the occasion of Réaumur's visit to Stockholm in 1724, when Swedenborg met him. Among his many and various scientific writings the greatest is *Mémoirs pour servir à l'Histoire des Insectes.* Amsterdam, 1734-1749. 6 vols. But the many references in the present treatise to Réaumur relate to his papers in the *Histoire de l'Academie Royale des Sciences.* He died October 17, 1757.

Gassend (Pierre), one of the most eminent philosophers of France, was born at Champtercier, in Provence, on January 22, 1592. His studies were, at first, directed towards the methods of Aristotle, which, however, were afterwards abandoned in favour of the growing empiricism of the time. Eventually, while professor of mathematics in the Collége Royal at Paris, he published some works on Epicurus, whose philosophy he accepted. His most important work (*Syntagma philosophiæ Epicuri*) was one of these. He died at Paris, October 24, 1655. His principal works are the following :—

1. *Exercitationes paradoxicæ adversus Aristoteleos.* Amstelodami, 1624. Also 1649 and 1656.
2. *Epistolica dissertatio in qua præcipua principia philosophiæ Roberti Fluddi deteguntur.* Amstelodami, 1631.
3. *Disquisitio metaphysica adversus Cartesium.* 1642.
4. *De vita, moribus, et doctrina Epicuri libri octo.* Lugduni, 1647. Also 1656.
5. *Animadversiones in decimum librum Diogenis Laertii.* Lugduni, 1649. 3 vols. This is the work so frequently quoted by Musschenbroek.
6. *Syntagma philosophiæ Epicuri.* Lugduni, 1649.

Gassend's collected works were published by Montmort in 6 vols. folio, at Lyons, 1655. Also 1658, which edition was that used by Musschenbroek. It was published again, 1727, 1737, and 1770. In addition, a compendium of Gassend's doctrine was published in Paris, as *Abrégé de la philosophie de Gassendi,* 1675, and reprinted 1678 and 1684.

Gilbert (William), the most famous English scientist of the Elizabethan era, and whom Galileo himself considered enviably great, was called the "Galileo of Magnetism." He was born at Colchester about 1542, and was appointed, later, physician to the Queen, and, on her death, to the same position for James I. Gilbert is mentioned with respect in Bacon's *Novum Organum,* and of him Dryden has written, "Gilbert shall live till loadstones cease to draw." He was elected President of the College of Physicians in 1600, and died November 30, 1603. His principal works are as follow :—

1. *De magnete, magneticisque corporibus, et de magno magnete tellure.* Londini, 1600. This is the work cited in the preceding pages. It describes the author's discovery that the earth itself is a magnet, and thus that the pointing of the needle and the inclination of the dipping needle are explained. From it W. Barlow's *Magneticall advertisements* (also quoted herein) was partly compiled. It was reprinted at Stettin, 1628 and 1633, and at Frankfurt, 1629 and 1638. Though not quoted here by Swedenborg himself, he nevertheless had a copy of the original edition in his library.
2. *De mundo nostro sublunari philosophia nova.* Amstelodami, 1651. This was edited by J. Gruter, and published by the author's brother (also named William) after the author's death.
3. A short letter addressed to William Barlow, and appended to his *Magneticall advertisements; or divers pertinent observations, and approved experiments concerning the nature and properties of the loadstone.* London, 1616; which work is referred to in the present treatise.

Gregory (David) was born at Kinnairdie, in Banffshire, June 24, 1661. In 1691 he was chosen Savilian Professor of Astronomy at Oxford, and the next year became a Fellow of the Royal Society. Gregory died at Maidenhead, October 10, 1708. His principal works are:—

1. *Exercitatio geometrica de dimensione figurarum.* Edinurbi, 1684. An English version appeared first in 1745, of which a ninth edition was issued in 1780.
2. *Catopticæ et diopticæ sphæricæ elementa.* Oxonii, 1695. This was reprinted in Edinburgh, 1713, and an English translation by Sir William Browne in London, 1715 and 1735. To the last-mentioned was attached an Appendix, by J. T. Desaguliers, who is cited in the present treatise.
3. *Astronomiæ physicae et geometricae elementa.* Oxoniæ, 1702. This is the work quoted by Swedenborg in the

present work; it was much esteemed by Newton, whose system it illustrates, and it was the first to apply the law of gravitation. It was reprinted at Geneva, 1726, and this was the edition which Swedenborg owned. An English rendering was published in 1713 and 1726.

4. *Euclides quae supersunt omnia.* Oxoniæ, 1703. This was prepared for Dr Bernard's scheme for reprinting the works of ancient mathematicians, and includes both the Greek and Latin texts.

HALLEY (EDMUND) was born at Haggerston, London, October 29, 1656. At eighteen years of age he had observed the change in the variation of the compass, and at nineteen gave out a new method of determining the elements of the planetary orbits. That he might catalogue the fixed stars in the southern hemisphere, he made a voyage to St Helena. Having engaged himself upon the problem of gravity, and reached a definite point, he journeyed to Cambridge to consult with Newton, and the consultation resulted in the publication of Newton's *Principia*, the labour and expense of passing which through the press fell upon Halley. In 1698 he made a long voyage for the purpose of making observations on terrestrial magnetism, and published the results in his *General chart,* which is referred to in this work. In 1703 he was appointed Savilian Professor of Geometry at Oxford, and it was while there that Swedenborg studied under him in 1712, and later dedicated to him the little treatise on *Finding the East and West Longitude by means of the moon*, 1718; a work which the professor approved. In 1720 he was made Astronomer Royal, and died January 14, 1742. Besides translating from the Arabic the works of Apollonius, and providing many contributions for the *Philosophical Transactions,* he published the following works:—

1. *Catalogus stellarum Australium,* London, 1679.
2. *Theory of the variation of the magnetical compass.* London, 1683. A work quoted by Musschenbroek.
3. *A General chart; shewing at one view, the variation of the compass in all those seas where the English navigators*

were acquainted, 1701. This also is used in the present work.

4. *Synopsis astronomiae cometicae.* Oxford, 1705.
5. *Astronomical tables.* London, 1752. Published posthumously.

HEVELIUS (JOANNES) was born at Dantzic, January 28, 1611. He was the friend of Galileo and Mersenne, and Halley travelled to Dantzic to see him. He excelled Tycho Brahe as an observer; and was known both as a maker of instruments and an industrious writer. He died January 28, 1687. His principal works are the following :—

1. *Selenographia, sive Lunæ descriptio.* Gedani, 1647.
2. *Mercurius in sole visus Gedani, anno*, 1661. Gedani, 1662.
3. *Cometographia.* Gedani, 1668.
4. *Machina cœlestis.* Gedani, 1673, 1679.
5. *Annus climactericus, sive rerum Uranicarum observationum annus quadragesimus nous.* Gedani, 1685.
6. *Catalogus stellarum fixarum.* Gedani, 1687.
7. *Prodromus astronomiae.* Gedani, 1690.
8. *Firmamentum Sobieskianum,* 1690.

The works quoted by Musschenbroek in the foregoing treatise are nos. 2, 5, 6, and 7 above.

KIRCHER (ATHANASIUS) was born at Geisa, May 2, 1602, and was educated as a Jesuit. He became professor of philosophy, mathematics, and Oriental languages at Würzberg, whence he was driven in 1631, by the Thirty Years' War, to Avignon. From thence he travelled to Rome, where he died November 28, 1660. His works in physical science are :—

1. *Ars magnesia, hoc est, disquisitio de natura, viribus, et prodigiosis effectibus magneti.* Herbipoli, 1631.
2. *Magnes, sive de arte magnetica opus tripartitum.* Romæ, 1641; also 1654. An edition printed at Cologne, 1643, was used by Musschenbroek in his work, and was that owned by Swedenborg.
3. *Magneticum naturae regnum.* Romæ, 1667; also at Amsterdam in the same year, and Swedenborg's copy was of this edition.

4. *Mundus subterraneus, quo subterrestis mundi opificium universae denique naturae divitiae, obditorum effectum causae demonstrantur.* Amstelodami, 1665; also 1668 and 1678.

MUSSCHENBROEK (Pieter van), so extensively quoted in this work, was born at Leyden on March 14, 1692. Collaborating with his former tutor, W. J. S. van's Gravesande, he was largely the means of introducing the philosophy of Newton into Holland. After holding a professorship at Duisburg from 1719, he was, in 1723, appointed to the chair of natural philosophy and mathematics in the University of Utrecht, which, however, he resigned in 1739 for the professorship of mathematics in his native city. Offers had been made to him by other universities in Europe, but were declined. He died on September 19, 1761. His principal publications are:—

1. *Disputatio de aeris praesentia in humoribus animalibus.* Lug. Bat., 1715. Republished by A. von Haller, 1746.
2. *Epitome elementorum physico-mathematicorum.* Lug. Bat., 1726.
3. *Physicae experimentales et geometricae dissertationes.* Lug. Bat., 1729. This work is divided into five parts—(1) *Dissertatio physica experimentalis de magnete,* (2) *Dissertatio physica experimentalis de tubis capillaribus vitreis,* (3) *Dissertatio de magnitudine terræ,* (4) *Introductio ad cohaerentiam corporum firmorum,* and (5) *Ephemerides meteorologiae Ultrajectinae anni* 1728. The first of these is fully cited by Swedenborg herein, and was republished separately at Vienna, 1754. Nos. 2 and 3 were also published, together, at Vienna, 1753. And the whole was reprinted in the same place, 1756. Swedenborg's copy was of the first edition.
4. *Tentamina experimentorum naturalium captorum in Academia del Cimento.* Lug. Bat., 1731. This is a translation of *Saggi di Naturali Esperienze fatte nell' Accademia del Cimento* (prepared by the Secretary of the Academy), quoted in these pages,

with annotations, additional experiments, and an oration (which was translated into Swedish by Mårten Triewald, at Stockholm, 1736). The whole was republished at Vienna in 1756. Though not quoted here, Swedenborg had the edition of 1731.

5. *Elementa physicae conscripta in usus academicos.* Lug. Bat., 1734. This is an enlargement of No. 2. It was translated into French by Pierre Massuet, and published at Leyden, 1739.
6. *Introductio ad philosophiam naturalem.* Lug. Bat., 1762. A summary of all his previous works, begun in 1690, and completed and published, after the author's death, by Jan Lulofs. It was translated into French by Sigaud de la Fonde, and published in Paris, 1769.
7. *Compendium physicae experimentalis conscriptum in usus academicos.* Lug. Bat., 1762.

Newton (Isaac) was born at Woolsthorpe, in Lincolnshire, December 25, 1642, *o.s.* He studied, principally mathematics, at Trinity College, Cambridge, of which he was elected a Fellow in 1667, and took his M.A. in 1668. He became Lucasian professor in optics, 1669, and in 1672 was made a member of the Royal Society, and presided in 1703. His many discoveries in physical science are well known. In 1714 the question of finding the longitude at sea having been brought before the House of Commons, Newton was called to give evidence and criticise the methods proposed. Solutions were invited by the Admiralty, and one, which does not appear to have been accepted, was offered by Swedenborg, who assiduously studied Newton, even in his youth, and especially his *Principia*, which he valued highly. Like several prominent scientists of his time, Newton wrote on theological matters. but without satisfaction. He died, March 20, 1747. His chief scientific works—besides his contributions to the *Philosophical Transactions* of the Royal Society—are these :—

1. *Philosophiae naturalis principia mathematica.* Londini, 1687. Of this Swedenborg possessed a copy. It was enlarged, edited by R. Cotes, and republished at

Cambridge, 1713, which is the edition quoted by Musschenbroek in the present treatise.

2. *Arithmetica universalis, or an arithmetical composition for the use of the University of Cambridge*, 1707. Also 1732, 1752, and 1761; in English, 1720 and 1769; in French, 1802.
3. *Analysis per quantitatum series, fluxiones ac differentias.* Londini, 1711; also 1723; and in English, 1745.
4. *Lectiones opticae.* Londini, 1729; in English, 1728.
5. *The method of fluxions and infinite series.* London 1736; also, 1737; and in French, 1740.

An edition of Newton's complete works was published in London, 1779-1785.

Norman (Robert), who was not only the first to observe a certain experiment described in these pages, but was the first to make a scientific record of the needle's declination, was a mathematical instrument maker, of whom otherwise little is known. There are two works by him extant, as follow :—

1. *The newe attractive, containing a short discourse of the magneš or lodestone, and amongst other his vertues, of a new discovered secret, and subtill properties concernyng the declinyng of the needle touched therewith under the plaine of the horizon.* London, 1581. A small quarto, printed in black letter, and dedicated to William Borough, whose *Discovery of the variation of the compass or magneticall needle* is appended to the second edition, 1585, by whom also that edition was "newly corrected and amended." It was published again in 1596, 1614, 1720, and in Whiston's *Longitude*, 1721 (*q.v.*). G. Hellman has also reprinted the work in *Neudrucke von Schriften und Karten über Meteorologie und Erdmagnetismus*, 1898. The treatise is quoted by Musschenbroek.
2. *Safegarde to Saylers, or a great Ruttere.* Translated out of the Dutch. London, 1590. Reprinted in 1600, 1612, and 1640.

Riccioli (Giovanni Battista), not so much an astronomical observer himself as a collector of the observations of others,

was born at Ferrara, April 17, 1598. He was assisted in his labours by Grimaldus (cited herein), who made important discoveries upon light, and he gave to the principal places on the moon the names which are now used by astronomers. He died June 25, 1671. The following are his principal works :—

1. *Almagestum novum, astronomiam veterem novamque complectens.* Bonomiæ, 1651. 2 vols. Cited in the foregoing treatise.
2. *Geographiae et hydrographiae reformatae libri xii.* Bonomiæ, 1661. Also cited herein.
3. *Astronomia reformata.* Bonomiæ, 1665. 2 vols.
4. *Chronologia reformata et ad certas conclusiones redacta.* Bonomiæ, 1669.

Whiston (William), so much commended in the foregoing work, is mostly known for his polemical writings on Christian Evidences, and for his frequently printed translation of Josephus. He was born at Norton, in Leicestershire, on December 9, 1667. In 1701 he was appointed Newton's deputy at Cambridge, and succeeded him in 1703 ; but in 1710 was banished from the university on account of his theological views. Whiston was one of the first in London to illustrate his lectures on scientific subjects by experiments, and it is by reason of his care in this respect that he was chosen by the Royal Society to retry the experiments made by Brook Taylor, as stated in this work. At his house in Cross Street, Hatton Garden, he established a society for the promotion of primitive Christianity, to whose meetings several of the learned men of the day went. Dr Whiston died at Lyndon, August 22, 1752. The following are his scientific works :—

1. *A new theory of the Earth.* London, 1696. Republished at Cambridge, 1708, and at London, 1714, 1722, 1725, 1737 (to this edition an Appendix was added), and 1755. A German translation was published at Frankfurt, 1713.
2. *Praelectiones astronomicae.* Cantabrigiæ, 1707. An English version of this appeared in London, 1715 and 1728.

3. *Praelectiones physio-mathematicae.* Cantabrigiæ, 1710. Reissued in 1726. An English version was published in London, 1716.
4. *A course of mechanical, optical, hydrostatical, and pneumatical experiments.* London, 1713. In this Whiston collaborated with F. Hawksbee.
5. *A new method of discovering the longitude.* London, 1714. This was produced in conjunction with Humphrey Ditton. A work which was known to Swedenborg.
6. *The longitude and latitude found by the inclinatory or dipping needle.* London, 1719. A second edition was printed in 1721, with a historical preface to which was subjoined Norman's *Newe Attractive*, quoted herein. This is the edition often quoted by Musschenbroek in his treatise.
7. *The calculation of solar eclipses without parallaxes.* London, 1724.
8. *The longitude discovered by the eclipses . . . of Jupiter's planets.* London, 1738.

Wolff (Christian von), whose philosophy is so highly estimated in the *Principia*, was personally acquainted with Swedenborg and corresponded with him. He was born at Breslau on January 24, 1679. After his university studies he was called to the chair of mathematics at Halle in the year 1707. But he was persecuted by the Theological Faculty on account of his philosophy, and, leaving the university in 1723, went into Saxony. It was whilst here under the patronage of the Landgrave of Hesse that Swedenborg made his acquaintance. It had been Wolff's practice hitherto to lecture and write in German, but now he reviewed his former writings, and, treating their subjects more fully, arranged them in a series of Latin treatises. By the influence of Frederic II. of Prussia, Wolff was eventually recalled to Halle, and appointed Chancellor of the University. Here he died, April 9, 1754. His works on philosophy are as follow:—

1. *Anfangsgründe aller mathematischen Wissenschaften*, 1709.
2. *Elementa matheseos universae*, 1713, 1715, 2 vols. A second and better edition was issued in 1732-1733, and of this Swedenborg made use.

3. *Vernunfftige Gedancken von der Kraften des menschlichen Verstandes*, 1712.
4. *Vernünfftige Gedancken von Gott, der Welt, und der Seele des menschen, auch aller Dinge überhauft*, 1719.
5. *Allerhand nützliche Versuche, dadurch zu genauer Erkäntniss der Natur und Kunst der Weg gebrähnet wird.* Halle, 1721, 1722, 3 vols. Swedenborg possessed a copy of this. It was reprinted in 1726, 1727, 1729, and again in 1745, 1747.
6. *Vernünfftige Gedancken von den Würckungen der Natur.* Halle, 1713 ; also 1725 and 1746. It is the work several times quoted by Musschenbroek.
7. *Absicht der natürlichen Dinge*, 1726. Swedenborg had a copy of this work.
8. *Meinung von dem Wesen der Seele, H. Rudigers gegenmeinung.* Leipzic, 1727. A copy of this also was in Swedenborg's collection.
9. *Philosophia prima, sive Ontologia.* Francofurti et Lipsiæ, 1730. Swedenborg possessed and made a close study of this work. He quotes it in the foregoing treatise. It was reprinted in 1736.
10. *Cosmologia generalis.* Francofurti et Lipsiæ, 1731 Swedenborg had a copy of, and analysed this and the preceding work when preparing the present treatise, wherein he quotes it.
11. *Psychologia empirica.* Francofurti et Lipsiæ, 1732. Swedenborg also studied this work.

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